

Development and Application of Syndromic Surveillance for Severe Weather Events Following Hurricane Sandy

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ABSTRACT

Objective: Following Hurricane Superstorm Sandy, the New Jersey Department of Health (NJDOH) developed indicators to enhance syndromic surveillance for extreme weather events in EpiCenter, an online system that collects and analyzes real-time chief complaint emergency department (ED) data and classifies each visit by indicator or syndrome.

Methods: These severe weather indicators were finalized by using 2 steps: (1) key word inclusion by review of chief complaints from cases where diagnostic codes met selection criteria and (2) key word exclusion by evaluating cases with key words of interest that lacked selected diagnostic codes.

Results: Graphs compared 1-month, 3-month, and 1-year periods of 8 Hurricane Sandy-related severe weather event indicators against the same period in the following year. Spikes in overall ED visits were observed immediately after the hurricane for carbon monoxide (CO) poisoning, the 3 disrupted outpatient medical care indicators, asthma, and methadone-related substance use. Zip code level scan statistics indicated clusters of CO poisoning and increased medicine refill needs during the 2 weeks after Hurricane Sandy. CO poisoning clusters were identified in areas with power outages of 4 days or longer.

Conclusions: This endeavor gave the NJDOH a clearer picture of the effects of Hurricane Sandy and yielded valuable state preparation information to monitor the effects of future severe weather events. (*Disaster Med Public Health Preparedness*. 2016;10:463-471)

Key Words: syndromic surveillance, severe weather, hurricane, disrupted outpatient medical care, carbon monoxide poisoning

Hurricane Superstorm Sandy struck New Jersey on October 29, 2012, causing harm to the health of New Jersey residents and billions of dollars of damage to businesses, transportation, and infrastructure.¹ Since damaged infrastructure and displacement of persons may result in situations that are hazardous to public health, state and local public health departments play a large role in severe weather event surveillance, preparation, response, and recovery.

Following an extreme weather event, gastrointestinal illnesses may stem from food not stored at proper temperatures or ingestion of contaminated water,² and respiratory complaints may arise from communicable diseases spread in close living situations (ie, shelters), from airborne debris particles, or from mold growing on water-damaged portions of buildings.³ Widespread power outages may result in improper generator use, which can lead to carbon monoxide (CO) poisoning.⁴ The mental health of the general population may also be compromised as a result of the distress and grief concurrent with displacement and the stress of rebuilding or relocating.⁵

According to findings from the Sandy Child and Family Health Study, a large representative study of 1 million New Jersey residents potentially affected by Hurricane Sandy, housing damage after Hurricane Sandy often resulted in health problem profiles similar to those of communities living in deep poverty.⁶ Adults exposed to mold after the storm were 2 times as likely to experience mental distress and 2.5 times as likely to be diagnosed with asthma. Children in these damaged homes were more than twice as likely to have sleeping problems as children from undamaged homes and more than 4 times as likely to be sad or depressed.

In analyses conducted by Munich Re, a leading global reinsurance firm, 8 of the 10 costliest storms since 1980 have occurred after 2004. Hurricane Sandy was the second costliest storm surge on record, surpassed only by Hurricane Katrina.⁷ Because severe weather events are predicted to occur more frequently and with greater severity in the future, it is crucial for states to utilize syndromic surveillance systems to monitor and respond to severe weather-related conditions.⁸

The intrinsic goal of syndromic surveillance is to identify clusters of symptoms and respond before diagnoses are confirmed to allow for the early detection of outbreaks and subsequent mobilization of resources.⁹ Surveillance systems like these may have been spurred by fear of disease outbreaks from terroristic attacks,¹⁰ most notably the anthrax attacks of autumn 2001, but they have recently achieved success in helping systems cope with spikes in health care utilization after severe weather events,¹¹ influenza activity monitoring,¹² and health impacts related to air pollution incidents.¹³ With the advent of electronic medical records and the advancement of automated search-query systems, syndromic surveillance is now routinely done in near-real-time,¹⁴ using school absentee records, over-the-counter drug purchases, or as utilized by New Jersey Department of Health (NJDOH), emergency department (ED) chief complaints.¹⁵

The NJDOH initiated a plan to develop a suite of indicators to perform surveillance for severe-weather-related health concerns following the experience with Hurricane Sandy and the foreseeable need to be prepared for future severe weather events. First, NJDOH gathered a group of word-based indicators related to severe weather events. Second, NJDOH evaluated the key words of these indicators by comparing them with the International Classification of Diseases, 9th revision (ICD9), for those same patient visits during and after Hurricane Sandy. Third, NJDOH applied the selected severe-weather-related health indicators to classify all available emergency department data to retrospectively review trends related to Hurricane Sandy. NJDOH has implemented the severe weather indicators in the syndromic surveillance system and plans to utilize these indicators to support public health preparedness and response to weather and other hazardous events.

METHODS

EpiCenter

EpiCenter is a secure online system that collects, manages, and analyzes ED registration data in real time from acute care and satellite EDs in New Jersey. New Jersey has utilized Health

Monitoring System, Inc's, EpiCenter system for syndromic surveillance statewide since 2011. Prior to Hurricane Sandy, 85% (68 of 80) of all acute care hospitals and satellite emergency departments in New Jersey were connected to EpiCenter. The patient registration data collected in EpiCenter are from EDs. Chief complaints were used for the development of key word lists for each indicator in EpiCenter. EpiCenter analyzed chief complaints from each ED visit and classified each visit by indicators/classifiers or syndromes. A visit might be classified into more than one syndrome.

Severe Weather Indicators

NJDOH selected health and mental health conditions related to severe weather event surveillance to be included in the suite of severe weather indicators. A list of indicators related to Hurricane Sandy is presented in Table 1 with corresponding ICD9 codes. A few of the indicators including CO poisoning and respiratory illness were implemented in EpiCenter before Hurricane Sandy. In addition to these existing indicators in EpiCenter, NJDOH compiled a list of initial key words for newly selected severe weather indicators through a collaboration with researchers from the New York City Department of Health and Mental Hygiene (NYCDOHMH), the New York State Department of Health (NYSDOH), and Rutgers, The State University of New Jersey, New Jersey Medical School and School of Public Health.

Key Word Evaluation

NJDOH evaluated key words for Sandy-related indicators by comparing them with ICD9 codes assigned by facilities for those same patient visits during and after Hurricane Sandy. Because not all hospitals consistently report ICD9 codes to EpiCenter, the evaluation was limited to 11 hospitals with a higher rate (>80% in 9 facilities) of ICD9 code data completion. Of the 11 facilities used for this evaluation, 7 facilities were located in counties designated most impacted by Hurricane Sandy: Hunterdon, Middlesex, Monmouth, Morris, Ocean, Somerset, Sussex, and Union counties.¹⁶ Only cases with an ICD9 code (either admitting or final) were included in the evaluation.

TABLE 1

Severe Weather Event Indicators and Corresponding ICD9 Codes Related to Hurricane Sandy^a

Indicator	ICD9 Codes
Carbon Monoxide Poisoning	986, E868.2-3, E868.8-9, E982.0-1, 508.2
Mental Health: Anxiety/Adjustment Disorders	293.84, 300.0, 300.2-3, 300.9, 308.0-4, 308.9, 309.0-4, 309.8-9
Disrupted Outpatient Medical Care: Dialysis	V45.1, V56.0, V56.31-2, V56.8, 585.5, 586, 792.5
Disrupted Outpatient Medical Care: Medicine Refills	V68.1, V58.6
Disrupted Outpatient Medical Care: Oxygen Needs	V46.2, 428, 491-2, 494, 496, 769, 770.7, 516.34
Upper Respiratory Illness	033, 465.0, 465.8-9, 466, 480-488, 490
Respiratory Illness: Asthma	493, 786.07
Substance Use: Methadone/Opiate/Heroin	965.0-02, 965.09, E850.0-2, 304.0, 304.9, 305.5

^aAbbreviation: ICD9, International Classification of Diseases, 9th revision.

Cases identified from key word lists and matched ICD9 code were “true positives,” whereas cases that did not match ICD9 code were “false positives.” The evaluation process included 2 steps. First, “true positives” and other cases with matched ICD9 codes were examined to identify common text patterns and potential key words for additional inclusion in order to increase sensitivity. Second, false positives were examined to find possible exclusion key words in order to increase classifier specificity. The sensitivity, specificity, and positive predictive value (PPV) statistical measures were computed for both the initial key word list and the final key word list (with added inclusion and exclusion key words).

The evaluation time frame was October 1 through December 31, 2012, with the exception of mental-health-related illness and respiratory syndrome classifiers. Mental-health-related illness evaluation spanned December 1, 2013, through March 31, 2014, to reflect the anecdotally observed trends in mental-health-related ED visits after Hurricane Sandy—a short-lived peak immediately following the storm, with a steady increase in mental-health-related visits over the next several months among those EDs in the most storm-impacted counties. Respiratory syndrome classifiers were evaluated by using a subset of the time frame: the week of October 26 through November 2, 2012. The shorter evaluation time period reflected the acute nature of these complaints and the higher frequency of ED visits.

SAS 9.3 was used to provide statistical analysis for sensitivity, specificity, and PPV computation. Through collaboration with subject matter experts and through the evaluation of the statistical measurements, a final set of key word lists was created for each selected indicator.

Severe Weather Indicator Application

NJDOH implemented the severe weather indicators into EpiCenter by using the final set of key words. Daily trends for

indicators related to severe weather during the 2 weeks before and after Hurricane Sandy were analyzed by using the Cumulative Sum with Exponential Moving Average (CUSUM EMA) method in EpiCenter. Application of Hurricane Sandy-related indicators was applied by comparing the trends of 1-month, 3-month, and 1-year time periods following Hurricane Sandy against the same time period from the following year. Statewide data including all facilities connected to EpiCenter prior to Sandy were used rather than solely data from the original 11 evaluation hospitals.

In addition to time trend analysis, cluster analysis using both space and time parameters was conducted to evaluate the geographical clusters for Sandy-related classifications. SaTScan v9.3 (Martin Kulldorff, Harvard Medical School, Boston, MA) provided cluster analysis for severe weather classifications using the time-space permutation method. Cases with resident zip codes outside New Jersey or without zip codes were excluded. ArcGIS 10.3 for Desktop (Esri, Redlands, CA) was used to provide visualization of the clusters identified. ED visits related to Sandy-related indicators were also grouped by impacted areas to evaluate the health outcomes by impact levels.

RESULTS

Severe Weather Indicator Key Word Evaluation

Sensitivity, specificity, and PPV on selected indicators for severe weather surveillance specifically for Hurricane Sandy are listed in Table 2. Key word lists including initial and final key words for indicators related to Hurricane Sandy are listed in Table 3.

For the CO poisoning indicator that was implemented in EpiCenter prior to Sandy, the initial key words included in EpiCenter indicated high sensitivity, specificity, and PPV. We included 2 new key words and excluded 2 additional key words suggested by the NJDOH Environmental and

TABLE 2

Sensitivity, Specificity, and Positive Predictive Value of Selected Severe Weather Event Indicators Related to Hurricane Sandy^a

Classifier	Initial Key Words (%)			Final Key Words (%)		
	Se	Sp	PPV	Se	Sp	PPV
Carbon Monoxide Poisoning	95.2	99.9	77.6	95.2	99.9	77.6
Mental Health: Anxiety/Adjustment Disorders	58.5	99.8	76.5	58.6	99.9	77.6
Disrupted Outpatient Medical Care: Dialysis	20.0	99.9	23.5	80.0	99.9	53.3
Disrupted Outpatient Medical Care: Medicine Refills	82.6	99.8	64.3	82.6	99.9	65.0
Disrupted Outpatient Medical Care: Oxygen Needs	2.3	99.8	10.5	61.6	96.6	16.6
Upper Respiratory Illness	87.2	91.7	41.9	76.2	98.5	77.4
Respiratory Illness: Asthma	45.5	99.5	55.6	73.6	99.4	60.4
Substance Use: Methadone/Opiate/Heroin	65.9	99.8	9.8	65.9	99.9	17.7

^aAbbreviations: PPV, positive predictive value; Se, sensitivity; Sp, specificity.

TABLE 3

Key Words for Severe Weather Event Indicators Related to Hurricane Sandy^a

Severe Weather Indicator	Initial Key Words		Final Key Words	
	Key Words Included	Key Words Excluded	Key Words Included	Key Words Excluded
(1) Carbon Monoxide Poisoning	CARBON MONOXIDE, TOXIC FUME, SMOKE INHAL, CARBON MONO, CO EXP, CO ₂	SUICI, SELF-INFLICTED, HOMICIDE, LEGAL INTERVENTION, TERRORISM, OPERATIONS OF WAR	CARBON MONOXIDE, TOXIC FUME, SMOKE INHAL, CARBON MONO, CO EXP, CO ₂ , <u>EXHAUST GAS, EXHAUST</u>	SUICI, SELF-INFLICTED, HOMICIDE, LEGAL INTERVENTION, TERRORISM, OPERATIONS OF WAR, <u>EXHAUSTED, EXHAUSTION</u>
(2) Mental health related illness- Anxiety/Adjustment disorder	NERVOUS, ANXI, PANIC	ALCOHOL, ETHO, INTOX	NERVOUS, ANXI, PANIC, <u>POST-TRAUMATIC STRE, PTSD, POST TRAUMATIC STRE, POSTTRAUMATIC STRE, ADJUST, ACUTE STRE</u>	ALCOHOL, ETHO, INTOX, <u>DEVICE, FITTING, NONPSYCHOTIC DISORD NOS, FIT/ADJUST</u>
(3) Disrupted outpatient medical care- Dialysis	DIALYSIS, PERITONEAL, HEMODIALYSIS, DIALYSIS, DIALYSIS	WOUND, SWELLING, PAIN, NECK PAIN, INFECTED, INFECTION, FEVER, CHILLS, CHEST PAIN, CATHETER PROBLEM, BLEEDING, ABD PAIN, ABDOMINAL PAIN	DIALYSIS, PERITONEAL, HEMODIALYSIS, DIALYSIS, DIALYSIS, <u>KIDNEY FAILURE, RENAL FAILURE</u>	WOUND, SWELLING, PAIN, NECK PAIN, INFECTED, INFECTION, FEVER, CHILLS, CHEST PAIN, CATHETER PROBLEM, BLEEDING, ABD PAIN, ABDOMINAL PAIN
(4) Disrupted outpatient medical care- Medicine refills	REFILL, MED FILL, RX FILL, MEDS, OUT OF MEDS, NEEDS MEDS, NEED MEDS, NEED RX, RAN OUT OF MEDS	NON COMPLIANT, NONCOMPLIANT, REFUSING, REACTION, INTERACTION, SIDE AFFECT, BREAK OUT TO, TOOK, INCORRECT, WRONG, INGESTED, INGESTION	REFILL, MED FILL, RX FILL, MEDS, OUT OF MEDS, NEEDS MEDS, NEED MEDS, NEED RX, RAN OUT OF MEDS, <u>ISSUE REPEAT PRESCRIPT</u>	NON COMPLIANT, NONCOMPLIANT, REFUSING, REACTION, INTERACTION, SIDE AFFECT, BREAK OUT TO, TOOK, INCORRECT, WRONG, INGESTED, INGESTION, <u>WITHDRAWAL, DETOX</u>
(5) Disrupted outpatient medical care- Oxygen needs	BREATHING TREATMENT, BREATHING TX, CPAP, NEBULIZER, NEB TREATMENT, OXYGEN, O ₂ , RESPIRATOR NO POWER, VENTILATO	CO ₂	BREATHING TREATMENT, BREATHING TX, CPAP, NEBULIZER, NEB TREATMENT, OXYGEN, O ₂ , RESPIRATOR NO POWER, VENTILATO, CHF, CHR BRONC, CHR AIRWAY OBSTR, DIFF BREATH, <u>DIFFICULTY BREATHING, EMPHYSEMA, HEART FAIL</u>	CO ₂
(6) Upper respiratory illness	Under EpiCenter “Infectious Disease Symptoms” classifier- “Cough,” “Congestion”, “Ears, Nose, Throat,” and “Respiratory” category ^b		URI, UPPER RESP, THROAT SORE, THROAT HURTS, STUFFY, STREP, SPUTUM, SORETHR, SORE THROA, SORE THR, SORE THOR, SORE THOA, RUNNY NOSE, RUNNING NOSE, RHINORRHEA, RHINOR, RESPIRATORY INFECTION, PNUEM, PNEUM, PNEMON, PLEURI, PHARYNG, PERTUSSIS, PAINFUL WITH BREA, PAINFUL BREAT, PAIN WHEN BREA, NOSE RUNNING, NASAL, LUNG PAIN, INFLUENZA, <u>_ILI, HURTS TO SWALLOW, HOARSE, FLULIKE, FLU, CROUP, COUGH, CORYZA, CONJEST, CONGEST, COLD, COIGH, BRONCH, BARKY, ILL</u>	BILI, VAG, URIS, URIN, URIE, URIC, URIA, SYR, STOMACH FLU, SEPTUM, PULM, HEART, FLUSHO, FLU SHOT, FLU SHOST, FLU SHOOT, FLU SHO, CHF, BRONCHOSPASM, BRONCHOSCOPY
(7) Respiratory illness-Asthma	Under EpiCenter “Exacerbation” category ^b		WHEEZ, ASTHMA, WHZ, ASHMA, BRONCHOSPASM, ASTH, ATHS, ATHSMA	
(8) Substance use- Methadone/Opiate/Heroin related	POSS OD, WITHDRAW, OPIAT, OPIOI, HERON, HEROIN, METHODI, METHADO, METHODO	ALCOH, ETHO, ETOH, PSYCH, NEC-UNSPEC	POSS OD, WITHDRAW, OPIAT, OPIOI, HERON, HEROIN, METHODI, METHADO, METHODO	ALCOH, ETHO, ETOH, PSYCH, NEC-UNSPEC, DRUG DEPEND NOS-UNSPEC, POLY SUB, <u>SUB ABU, DRUG ABU, SUBSTANCE</u>

^aUnderlined key words indicate additions to the initial key words.

^bInformation available to EpiCenter users only.

Occupational Surveillance team to the existing list to capture exhaustion gas exposure.

The initial EpiCenter key word list for the anxiety/adjustment disorders classifier resulted in a sensitivity of 58.5%, a specificity of 99.8%, and PPV of 76.5%, whereas the updated key word lists resulted in slight increases in both sensitivity and specificity, to 58.6% and 99.9%, respectively, and a concurrent slight increase in PPV to 77.6%.

For disrupted outpatient medical care, sensitivity quadrupled for dialysis when the updated key word list was used, rising from 20% to 80%. No additional exclusion key words were proposed, so specificity stayed constant at 99.9% and PPV rose from 23.5% to 53.5%. For medicine refills, sensitivity and specificity stayed the same, at 82.6% and 99.9%, respectively, and PPV increased slightly from 64.3% to 65%.

For oxygen needs, out of 86 ICD9-matched cases, only 2 cases matched the initial proposed key words, resulting in a PPV of 10.5% and a sensitivity of 2.3%. After additional key words were identified, sensitivity increased to 61.6% and PPV increased to 16.6%.

Upper respiratory illness, the initial key word lists for which were created from subcategory lists in EpiCenter's "infectious disease" classifier, began with a sensitivity of 87.2%, a specificity of 91.7%, and a PPV of 41.9%. The updated upper respiratory illness key word list decreased sensitivity to 76.2% while increasing specificity to 99.4%, which resulted in a net increase in PPV to 77.4%. Asthma was also evaluated, beginning with a sensitivity of 45.5%, a specificity of close to 100%, and a PPV of 55.6%. For this syndrome classifier, the updated list increased sensitivity to 73.6% and PPV rose to 60.4%.

For substance use, the sensitivity for the methadone/opiate/heroin-related classifier remained the same but the PPV remained low (17.7%) despite the addition of several exclusion key words.

Severe Weather Indicator Application

NJDOH implemented the severe weather indicators into EpiCenter by using the final set of key words. When the time period after Hurricane Sandy was compared to the same time period during the following year, the impact of the extreme weather event on increases in ED visits for each of the evaluated syndromes became clear (Figure 1). Spikes in overall ED visits can be seen in late October and early November 2012 (immediately after the hurricane) for CO poisoning, the 3 disrupted outpatient medical care indicators, asthma, and methadone/opiate/heroin-related substance use. Peaks of this magnitude are not seen in the comparison time period in 2013-2014. For these classifiers, the peak was sufficiently captured on a 1-month timeline, which as a result

is the recommended time period to follow these syndromes after a severe weather event. The CUSUM EMA method also generated alerts for these classifications.

Not all increases were captured on a 1-month timeline. When looking at the classifier for upper respiratory infections, a post-storm increase was seen in late December 2012/January 2013. The magnitude of this increase was not matched during the same time period in 2013-2014 and may reflect the persistent displacement, overcrowding, or habitation in water-damaged home structures that many New Jersey residents were still experiencing months after Hurricane Sandy. It may also have been due to the difference in the peak months of influenza season in 2012-2013 from 2013-2014.

No evidence of increased anxiety/adjustment disorders could be seen at the state level until data were stratified by more/less affected counties, after which an immediate post-storm spike could be seen. As well, a gradual divergent increase began in May 2013 and continued through spring of 2014.

Scan statistics at the zip code level indicated 6 clusters among cases with CO poisoning concerns and 1 cluster with significantly increased needs for medicine refills during the first 2 weeks of Hurricane Sandy by using a cluster radius limitation of 5 miles. CO poisoning clusters were identified in northeast counties of New Jersey and along the shore (Figure 2). The CO clusters were detected from areas with power outages of 4 or more days estimated from the duration of area school closings listed by Hoopes Halpin.¹⁶

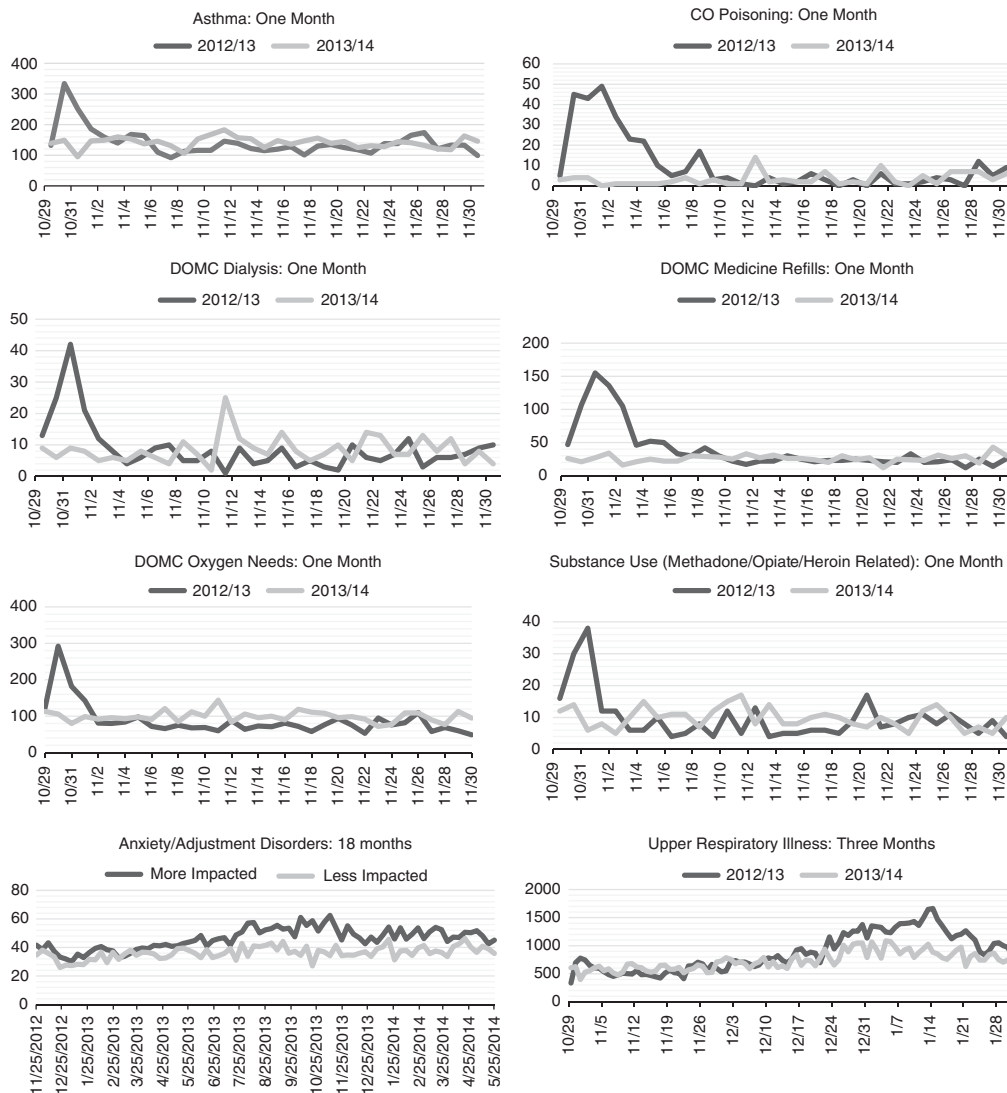
DISCUSSION

NJDOH evaluated severe weather indicators to aid in the monitoring of future extreme weather event health hazards. Refining these measures allowed a clearer look at ED use after severe weather events by muting the "background noise" of endemic disease and resulted in new information about the frequency and timeline of certain syndromes after a severe weather event. To our knowledge, this is the first assessment evaluating accuracy measures of a set of severe weather indicators and presenting the application of selected severe weather event syndromic surveillance classifiers following Hurricane Sandy. The final key word lists for anxiety/adjustment disorders, disrupted outpatient medical care (dialysis and medication refills), upper respiratory illness, and asthma resulted in improved accuracy compared with initial key word lists and are recommended for use when analyzing severe weather events.

For indicators with lower PPVs (eg, oxygen needs and methadone use), it seems infeasible to apply the same approach of using diagnostic codes for key word inclusion and exclusion practice. The reason for the low PPV for the oxygen needs classifier is perhaps the many records that are associated with the targeted key word "difficulty breathing."

FIGURE 1

Frequencies of Selected Post-Severe-Weather-Event Syndromes, Over Recommended Time Periods of Surveillance.



Abbreviations: CO, carbon monoxide; DOMC, disrupted outpatient medical care.

This term is also used by many other respiratory symptoms that do not result in the need for supplementary oxygen, which thus results in many false positives. As for the methadone use classifier, the proposed key words were sensitive for the tracking of methadone/opiate/heroin ED visits during Hurricane Sandy.

This evaluation was limited by EpiCenter's ability to process ICD9 coding from only 11 locations. Although most of these facilities were located in the parts of New Jersey most severely affected by Hurricane Sandy, they may not have been representative of the key word patterns statewide. For some syndromes, ICD9 codes were not sufficiently specific to differentiate between true and false positives, making

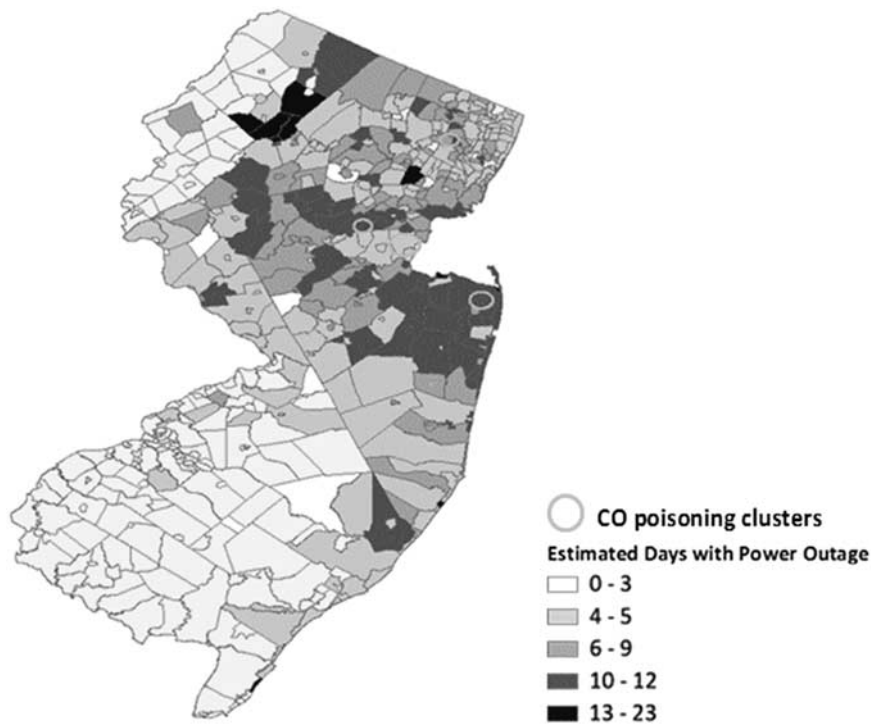
accuracy measures difficult to ascertain. In addition, this study only applied ICD9 codes as a standard for key word evaluation. Further evaluation to include newly implemented ICD10 codes may better refine the quality of key words for selected indicators.

Application of indicators was performed by using Hurricane Sandy as the severe weather event. Depending on the nature or severity of an event, findings are likely to differ. Most classifiers become more accurate in larger or more severe events.¹⁷

Literature on severe weather event health outcomes reinforces the need to perform surveillance after a severe weather

FIGURE 2

Clusters of Carbon Monoxide (CO) Poisoning with Estimated Days of Power Outage by Municipality.



event as well as to expand surveillance evaluations and application. Following landfall of Hurricane Sandy, disrupted medical care for dialysis, medicine refills, and oxygen needs represented a major contributor to ED visits. A marked increase in overall hospitalizations related to continuity-of-care was seen in Reunion Island (France) following Tropical Cyclone Bejisa in 2014, particularly related to existing chronic disease and oxygen needs following a power outage.¹⁸ An increase in hospitalizations for dialysis was noted after heat waves in Australia. This was thought to likely be due to a combination of dehydration and heat stress.¹⁹ An extensive literature review completed by Ochi et al²⁰ in 2014 found that medication loss during evacuations was highly common and placed a considerable burden on emergency medical relief teams and EDs. In addition, many evacuees lose essential medical aids such as insulin pens or hearing aids, creating additional need. Their review also revealed difficulty in refilling prescriptions owing to a lack of information from the evacuees and urged that emergency preparation should include a section on the importance of remembering medications and medical aids.²⁰ In their assessment of functional needs sheltering in Pike County, Kentucky, following a series of severe weather events, Kolwaite et al²¹ found similar results regarding prescription medications and also found that 12% of residents in areas marked for evacuation used supplemental oxygen regularly.

In addition to the NJDOH application, the NYCDOHMH and the NYSDOH have applied syndromic surveillance to evaluate the CO poisoning incidences associated with Hurricane Sandy.^{4,22} Each jurisdiction applied the preexisting key word during and after Hurricane Sandy for the evaluation. The CDC Sandy Recovery funding for all 3 health departments has provided the opportunity to work together to develop and refine indicators related to severe weather and to explore the potential for regional data and information sharing plans for future events.

The New York City Poison Control Center also found a significant incidence of CO poisoning in the 2 weeks following Hurricane Sandy.⁴ A significant CO poisoning increase in the 5 days after Tropical Cyclone Bejisa¹⁸ was also observed. These assessments agree with our findings regarding the severity and immediacy of CO poisoning after a severe weather event.

Following Hurricane Sandy, we did not find a meaningful increase in gastrointestinal illness using an existing EpiCenter gastrointestinal illness indicator; however, findings from recent floods in the United States did detect an increase.^{2,23}

Acute upper respiratory infections have long been known to fluctuate with weather patterns. For some upper respiratory infections, a biennial rhythmicity has been described, and for

others, an annual seasonal variation can be seen. Findings from Costilla-Esquivel et al²⁴ posit that cyclical weather factors may affect the ease of transmission of viruses, the viability of said viruses, and the immune system strength of potential hosts. Their weather-index model measuring temperature, humidity, and rainfall accurately predicted 76% of the variance in upper respiratory infection counts in Mexico.²⁴ Furthermore, there are many potential asthma triggers that become more prevalent in the aftermath of severe weather events. Goskel et al²⁵ found that weather changes were among the most common non-allergenic asthma triggers in adults, particularly in severe cases. In addition, patients with severe asthma are more likely to report stress as a trigger, which may make sufferers more vulnerable to asthma attacks during and immediately following a severe weather event.²⁵ The effects described by Kolwaite et al²¹ and Ochi et al²⁰ regarding medication loss during evacuation may also result in higher asthma-related ED visit rates. It may be useful to apply the asthma key word list during heat waves as well, because significant increases in asthma and wheezing have previously been detected as the result of heat wave-induced poor air quality.¹⁴

It is recommended that “anxiety/adjustment disorders” be monitored for a longer time period, on the scale of 1 year or longer. The choice to stratify the anxiety/adjustment disorder data by less affected/more affected counties revealed a late-onset increase in ED visits that concurs with the conclusions in MacFarlane and Williams⁵—that intensity of exposure is an important factor in risk of adverse mental health outcomes and that psychosocial interventions for medium- to long-term morbidity is recommended in the wake of disaster.

The results from this study have been shared with the New Jersey Sandy Recovery team including state emergency preparedness staff for future event preparation and at national and regional meetings of epidemiologists for experience sharing. In addition, the EpiCenter Severe Weather Indicators have been introduced to the local health department preparedness staff before a recent snowstorm occurred in early 2016. Elevated CO poisoning and increased dialysis needs were observed in the recent snowstorm.

The unavailability of syndromic surveillance infrastructure during severe weather events such as flooding or hurricane may interrupt real-time data collection. NJDOH has established a mobile device accessible survey prior to implementing the statewide electronic syndromic surveillance system. The established survey tool can be used for situation awareness as a backup plan when the syndromic surveillance infrastructure is damaged.

CONCLUSIONS

Development of a suite of extreme weather event health and mental health indicators improved NJDOH’s situational awareness in real time during extreme weather events.

The implemented severe weather indicators have been introduced to the state and local emergency preparedness team. NJDOH will use these indicators to set thresholds to generate automatic alerts. NJDOH was able to use Hurricane Sandy and the resulting aftermath as a point of entry to evaluate and refine existing key word lists for severe weather event syndromic surveillance. Utilization of real-time chief complaint surveillance allowed NJDOH to receive important situational awareness information from New Jersey’s EDs without impacting their ability to perform their work during the days, weeks, and months following the storm. The magnitude of Hurricane Sandy’s impact, both in terms of monetary damage and the number of people affected, makes this a unique severe weather event for the analysis of health effects. Given that storms are predicted to increase in occurrence and force in the future, the syndromes and classifiers, and the process by which NJDOH evaluated and refined their key word lists, could be useful for health departments and others involved in emergency preparedness to gauge the health impact of a severe weather event and prepare for a response.

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