Impact of a Natural Disaster on Diabetes

Exacerbation of disparities and long-term consequences

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OBJECTIVE — To examine the impact of Hurricane Katrina on the health of individuals with diabetes.

RESEARCH DESIGN AND METHODS — This was an observational study in 1,795 adults with an A1C measurement 6 months before and 6−16 months after Hurricane Katrina in three health care systems: private (Tulane University Hospital and Clinic [TUHC]), state (Medical Center of Louisiana at New Orleans [MCLNO]), and Veterans Affairs (VA). Glycemic control (A1C), blood pressure, and lipids before the hurricane were compared with the patients' first measurement thereafter. The CORE Diabetes Model was used to project life expectancy and health economic impact.

RESULTS — Mean predisaster A1C levels differed between MCLNO and VA patients (mean 7.7 vs. 7.3%, $P < 0.001$) and increased significantly among MCLNO patients to 8.3% ($P < 0.001$) but not among VA and TUHC patients. Mean systolic blood pressure increased in all three systems (130–137.6 mmHg for TUHC and 130.7–143.7 for VA, $P < 0.001$; 132–136 for MCLNO, $P = 0.008$). Mean LDL cholesterol increased in the VA (97.1–104.3 mg/dl) and TUHC patients (103.4–115.5; $P < 0.001$). Hurricane Katrina increased modeled direct, indirect, and total health care costs and also reduced life expectancy as well as quality-adjusted life expectancy, with the economic impact being quite substantial because of the large population size affected. We estimate a lifetime cost of USD $504 million for the adult population affected, with the largest economic impact seen among MCLNO patients.

CONCLUSIONS — A major disaster had a significant effect on diabetes management and exacerbated existing disparities. These effects may have a lasting impact on both health and economic implications.

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Hurricane Katrina struck New Orleans in August 2005. Although the economic and environmental devastation caused by the hurricane is well known and the short-term impact on health care and health care delivery has been well described (1), the impact on chronic disease has not been well documented. Our personal experience and anecdotal information suggest that individuals with diabetes were very seriously affected owing to the lack of medical care, appropriate food, and medications (2). Diabetes is a chronic disease with many comorbidities, including hypertension and lipid abnormalities. Disruption of health care provisions and medications is likely to have both a short-term and long-term impact on this condition. We tested the following hypotheses: *1*) Hurricane Katrina has had a significant impact on the health of individuals with diabetes; *2*) this impact will have long-lasting health and economic implications; and *3*) preexisting disparities between health systems will be worsened and lead to further disparity in health status.

RESEARCH DESIGN AND METHODS

— This study was approved by the Tulane Human Research Advisory Committee. The collection of data were considered to be exempt from needing informed consent.

Study population

Tulane University Health Sciences Center is a major provider of health care in the city of New Orleans and has established long-standing diabetes care centers within three health care systems with the patients grouped accordingly:

A. Private hospital and clinic (Tulane University Hospital and Clinic [TUHC]). TUHC reopened clinics in January 2006. However, clinics, including a diabetes clinic, reopened within a few weeks at nearby undamaged Tulane University partner hospitals. Thus, private patients (usually with health insurance) had access to a diabetes center within a few weeks after the hurricane.

B. Southeast Louisiana Veterans Health Care System (VA), a system available almost exclusively to veterans. The VA hospital reopened outpatient primary care clinics in New Orleans 3 months and specialty clinics 5 months after the hurricane. In addition, veterans had access to VA services and medications in other parts of the state and country.

C. The Medical Center of Louisiana at New Orleans (MCLNO), "Louisiana Charity System." This state-funded system provides acute and chronic care for all patients irrespective of insurance status, with a significant proportion of uninsured patients: MCLNO specialty clinics were closed for >1 year after the hurricane. However, primary care was available at a variety of community clinics,

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Table 1—*Characteristics of the study population*

	Total	TUHC/private	VA	MCLNO/ public	*P*
n	1,795	452	748	595	
Age (years)	61.9 ± 11.6	58.6 ± 13.5	66.4 ± 10.5	58.7 ± 9.2	<0.0001
Sex (male)	61.2	44.9	96.9	28.7	<0.0001
Race					
Caucasian	39.3	44.9	55.1	15.1	<0.0001
African American	56.9	51.3	40.2	82	<0.0001
Other	3.8	3.8	4.7	2.9	<0.0001

Data are means ± SD or %.

with fragmented health care services. No diabetes-specific specialty clinic was available for these patients for ~1 year.

The characteristics of the patients studied are summarized in Table 1. We believe that this information reflects reasonably accurately the characteristics of the patients with diabetes in each system. There are no major differences among the provider characteristics in the three systems, with many providers working in more than one system.

Adults with diabetes and an A1C measurement 6 months before Hurricane Katrina (28 February 2005–27 August 2005) and 6−16 months after Hurricane Katrina (1 March 2006–31 December 2006) were identified from databases within these three health care systems. All patients seen at TUHC and MCLNO who had such measurements were included in the study population. Because there were considerably more such patients in the VA system, we randomly selected 750 patients for this study, among whom 748 had data available for all study-related parameters. After identification of these patients, their other laboratory parameters (lipids) were obtained and their charts were reviewed for blood pressure measurements that occurred within the study time period.

We compared the level of glycemic control (A1C), blood pressure, and lipids in patients for whom data were available in the 6-month period before the hurricane with levels after resumption of clinical activities (1 March 2006–31 December 2006). No specific intervention or recommendations were made. In patients who had multiple measurements of A1C, blood pressure, or lipids, the values at the last visit of the pre-Katrina period and the first visit of the post-Katrina period were included in final analysis.

Data sources

Laboratory data at all three institutions were computerized and were available for both time periods. TUHC used a computerized medical record for all laboratory data and some clinical data. Medical records for most patients previously seen at TUHC were intact. All laboratory and clinical data at the VA were electronically available. Laboratory records at MCLNO were computerized, but data on blood pressure were only available for a subset of patients, whose clinic records were salvaged.

Statistical analysis

Primary outcomes were A1C, systolic and diastolic blood pressures, and lipids. We were interested in the changes in these parameters before and after Hurricane Katrina and whether these changes were consistent across the three health care systems. Paired sample *t* tests were performed for pre- and post-Katrina mean values of A1C, blood pressure, and lipids within each system. One-way ANOVA with a post hoc Bonferroni correction was used to determine whether the above-mentioned pre- and post-Katrina measurements differed among the three systems.

Linear regression models were also fitted for the changes in the three primary outcomes. Changes in A1C, blood pressure, and lipids were calculated by subtracting pre-Katrina values from post-Katrina values. These changes were used as dependent variables. Covariates included in the models were health care system, patients' age in August 2005, sex, and "time gap." Time gap was defined as the number of months between the pre- and post-Katrina measurements. Because patients did not necessarily have parameters measured on the same day, the time gaps for different outcomes could be different for each patient. These analyses were performed in SAS (version 9.1.3 for Windows, 2005; SAS Institute, Cary, NC).

Modeling for possible long-term outcomes was performed using the CORE Diabetes Model (CDM), a documented, validated simulation model for type 2 diabetes that projects life expectancy, quality-adjusted life expectancy (QALE) and total lifetime costs of diabetes-related complications (3). The transition probabilities using the UK Prospective Diabetes Study (UKPDS) studies, U.S. costs of complications, and health state utilities were detailed in the previous publication (3). For instance, the underlying assumption for A1C changes based on the UKPDS cohort was a linear decay at a rate of 0.15%/year until the end of 7 years, with the decay leveling off for the rest of lifetime. The model is a multilayer Internet application using SQL and C++ programming languages and a user interface to enter customized settings of the results from the tests described above to specifically define an analysis and output the results. For this study, the simulations were run over a lifetime horizon in accordance with the current guidelines that recommend time horizons be sufficient to capture the development of all relevant complications (4,5). Specifically, this model estimates lifetime survival and costs for those who survived the hurricane and may have experienced disruption of treatment or deprivation of insulin and other medication over a period of time.

We ran the CDM for each of the three health care system populations. The mean changes in A1C, blood pressure, and lipids generated by the analyses of data before and 6–16 months after Hurricane Katrina among the study populations were populated into the input databases of the CDM. In addition, the SDs around the mean changes were also included to account for the uncertainty around the effects on glycemic control. Demographic information such as age, race, and sex for the study sample was used, whereas weight and smoking status used for the model were the CDM default values (i.e., the U.S. prevalence of smoking status and body weight distribution). The CDM has 16 submodels that run in parallel for which 1,000 patients are run through the model 1,000 times to account both for patient level uncertainty and parameter level uncertainty for model inputs. The output via user interface provided a set of

Table 2—*Clinical and laboratory parameters among diabetic patients in three health care systems before and after Hurricane Katrina (28 February 2005–27 August 2005 and 1 March 2006–31 December 2006)*

	n	Pre-Katrina mean value	Post-Katrina mean value	Difference in mean value	Patients with increased values*	Patients with decreased values†	Patients had no changes‡	*P* for change in mean value
A1C (%)								
TUHC	452	7.5 ± 1.6	7.4 ± 1.8	−0.1 ± 1.4	107 (23.67)	181 (40.04)	164 (36.28)	0.108
VA	748	7.3 ± 1.6	7.4 ± 1.6	0.1 ± 1.4	275 (36.76)	209 (27.94)	264 (35.29)	0.193
MCLNO	584	7.7 ± 1.9	8.1 ± 2.1	0.3 ± 1.8	279 (46.97)	149 (25.08)	166 (27.95)	<0.01
Total	1,794	7.5 ± 1.7	7.6 ± 1.9	0.1 ± 1.6	661 (36.85)	539 (30.04)	594 (33.11)	<0.01
Systolic blood pressure (mmHg)								
TUHC	262	130.0 ± 17.7	137.5 ± 21.6	7.5 ± 20.8	145 (55.34)	76 (29.01)	41 (15.65)	<0.01
VA	723	130.7 ± 16.6	143.7 ± 18.6	13.0 ± 20.5	505 (69.85)	158 (21.85)	60 (8.30)	<0.01
MCLNO	142	132.2 ± 17.7	136.0 ± 19.2	3.8 ± 17.1	84 (59.15)	41 (28.87)	17 (11.97)	<0.01
Total	1,127	130.7 ± 17.0	141.2 ± 20.0	10.5 ± 20.4	734 (65.13)	275 (24.40)	118 (10.47)	<0.01
Diastolic blood pressure (mmHg)								
TUHC	262	74.9 ± 11.0	76.3 ± 12.8	1.4 ± 13.7	115 (43.89)	91 (34.73)	56 (21.37)	0.093
VA	723	68.8 ± 12.0	74.2 ± 12.0	5.4 ± 12.8	418 (57.81)	183 (25.31)	122 (16.87)	<0.01
MCLNO	142	75.0 ± 10.7	75.5 ± 11.8	0.5 ± 11.6	61 (42.96)	52 (36.62)	29 (20.42)	0.597
Total	1,127	71.0 ± 12.0	74.9 ± 12.2	3.9 ± 13.1	594 (52.71)	326 (28.93)	207 (18.37)	<0.01
LDL cholesterol (mg/dl)								
TUHC	221	103.4 ± 32.6	115.5 ± 39.1	12.1 ± 34.6	141 (63.80)	45 (20.36)	35 (15.84)	<0.01
VA	607	97.1 ± 31.9	104.3 ± 36.2	7.2 ± 32.7	317 (52.22)	194 (31.96)	96 (15.82)	<0.01
MCLNO	343	107.9 ± 40.2	107.7 ± 41.4	−0.2 ± 39.6	155 (45.19)	142 (41.4)	46 (13.41)	0.948
Total	1,171	101.4 ± 35.0	107.4 ± 38.5	6.0 ± 35.5	613 (52.35)	381 (32.54)	177 (15.12)	<0.01
HDL cholesterol (mg/dl)								
TUHC	228	40.4 ± 13.6	43.5 ± 14.2	3.1 ± 9.5	120 (52.63)	45 (19.74)	63 (27.63)	<0.01
VA	543	42.1 ± 10.5	38.0 ± 11.9	−4.1 ± 8.6	91 (16.76)	338 (62.25)	114 (20.99)	<0.01
MCLNO	343	47.6 ± 13.6	44.2 ± 14.0	−3.4 ± 8.4	68 (19.83)	190 (55.39)	85 (24.78)	<0.01
Total	1,114	43.5 ± 12.5	41.0 ± 13.4	−2.4 ± 9.2	279 (25.04)	573 (51.44)	262 (23.52)	<0.01
Triglycerides (mg/dl)								
TUHC	233	153.2 ± 99.6	158.2 ± 118.0	5.1 ± 111.7	98 (42.06)	101 (43.35)	34 (14.59)	0.491
VA	543	172.8 ± 134.9	161.4 ± 108.2	−11.4 ± 119.9	206 (37.94)	247 (45.49)	90 (16.57)	0.027
MCLNO	344	147.1 ± 104.5	154.6 ± 203.2	7.5 ± 173.9	130 (37.79)	154 (44.77)	60 (17.44)	0.422
Total	1,120	160.8 ± 119.8	158.7 ± 145.7	−2.1 ± 137.5	434 (38.75)	502 (44.82)	184 (16.43)	0.601

Data are means ± SD or *n* (%). *A1C changes >+0.3, systolic blood pressure changes >+3, diastolic blood pressure changes >+3, LDL cholesterol changes >+5, and HDL cholesterol changes >+3, triglyceride changes >+10. †A1C changes <−0.3, systolic blood pressure changes <−3, diastolic blood pressure changes <−3, LDL cholesterol changes <−5, and HDL cholesterol changes <−3, triglyceride changes < −10. ‡A1C changes within ±0.3, systolic blood pressure changes within ±3, diastolic blood pressure changes within ±3, LDL cholesterol changes within ±5, and HDL cholesterol changes within ±3, triglyceride changes within ±10.

results (pre-Katrina and 6–16 months post-Katrina) from each set of simulations. These pre/post differences in the estimates from the 1,000 iterations, which measured the impact of Hurricane Katrina, were used to derive mean and SEM of life expectancy and QALE, as well as total cumulative direct, indirect, and combined costs (direct + indirect) over a lifetime. The individual patient's impact within each health system was tested for statistical inference using one-sample *t* tests. We further extrapolated the prevalence-based mean impact of an individual patient to the entire population in the greater New Orleans area using 2000 U.S. Census data. The following assumptions based on the Louisiana Department of Health and Hospital statistics report 2006 were made: MCLNO represented 20% of the population, VA represented 5%, and TUHC/privately insured represented 75%; the adult population affected in the greater New Orleans area was 964,677 adults; and an estimated diabetes prevalence of 9.2% obtained from the Centers for Disease Control and Prevention (http://apps.nccd.cdc.gov/brfss/) was used. Because of the methodological difficulty to produce a population SD from three sample SDs, a sensitivity analysis on lifetime costs was performed by varying 10% on sample mean costs.

RESULTS — A total of 1,795 patients with A1C measurements in the 6 months before Hurricane Katrina and the 6–16 months after the hurricane were included. Among them, 748 were VA patients, 595 were MCLNO patients, and 452 were TUHC patients. The mean age of all patients was 61.9 years and 61.2% were male. The MCLNO system consisted of >80% African American patients. The percentage of male patients (96.9%) was higher in the VA system compared with those in the TUHC and MCLNO systems (44.9 and 28.7%, respectively).

The impact of the disaster on clinical and laboratory parameters is summarized in Table 2. Mean A1C values increased significantly over the study period among the patients of the MCLNO system ($P < 0.001$); however, pre-Katrina A1C levels were similar to post-Katrina levels among patients of the VA and TUHC systems ($P = 0.214$ and $P = 0.108$, respectively). Mean pre-Katrina A1C levels significantly differed between MCLNO and VA patients ($P < 0.001$). Mean post-Katrina A1C values also significantly differed between the MCLNO and the other two systems ($P < 0.001$). Mean systolic blood pressures increased among all three systems ($P < 0.001$ for TUHC and VA; $P = 0.008$ for MCLNO). Mean pre-Katrina systolic blood pressures did not differ significantly among the three systems, whereas mean post-Katrina systolic blood pressure was significantly higher in the VA patients compared with patients in the other two systems ($P < 0.001$). Mean LDL cholesterol levels increased in both the VA and TUHC patients ($P < 0.001$). However, mean HDL cholesterol levels increased in the TUHC patients but decreased in the MCLNO and VA patients ($P < 0.001$). Mean triglyceride levels increased significantly in VA patients only ($P = 0.027$).

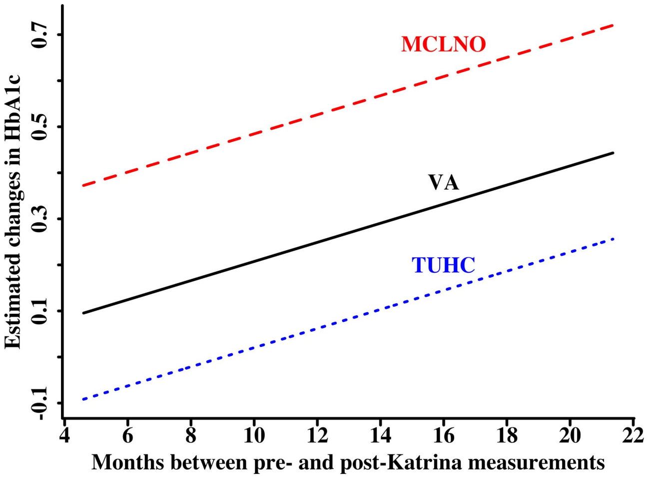

Figure 1—*Model of relationship between change in A1C and time in patients in three different health systems in New Orleans, before and after Hurricane Katrina.*

Linear regression models for the trend in the changes of the parameters indicated significant differences among the three systems ($P < 0.05$) over the time gaps ($P < 0.05$) for all parameters. Neither age nor sex was significant ($P > 0.05$) in any of the models. Figures 1, 2, and 3 illustrate the time relationship of A1C and blood pressure to the time after the disaster. Systolic and diastolic blood pressures increased early after the event and then gradually returned to baseline levels, whereas A1C levels increased throughout the observational period.

Hurricane Katrina increased direct, indirect, and total costs and reduced life expectancy as well as QALE (Table 3). The magnitude of the impact for each health care system was consistent with that of the clinical results. The largest economic impact was seen in MCLNO patients with $5,243 over their lifetime, followed by VA patients ($3,907), and privately insured TUHC patients ($2,270). Despite the fact that the impact on life expectancy seemed to be small (MCLNO patients -0.301 years, VA patients -0.264 years, and TUHC patients -0.078 years), the economic impact was quite substantial because of the large size of the population affected by Hurricane Katrina. Assuming that the adult prevalence of diabetes in the affected area was 9.2% (Centers for Disease Control and Prevention estimate in an adult population of approximately 1.0 million, 2000 U.S. Census data), we estimated a lifetime cost of USD $504 million for the population affected by Hurricane Katrina. A 10% variation around the mean cost of each sample produced an estimate of lifetime costs of USD $454–$555 million due to the impact of Hurricane Katrina.

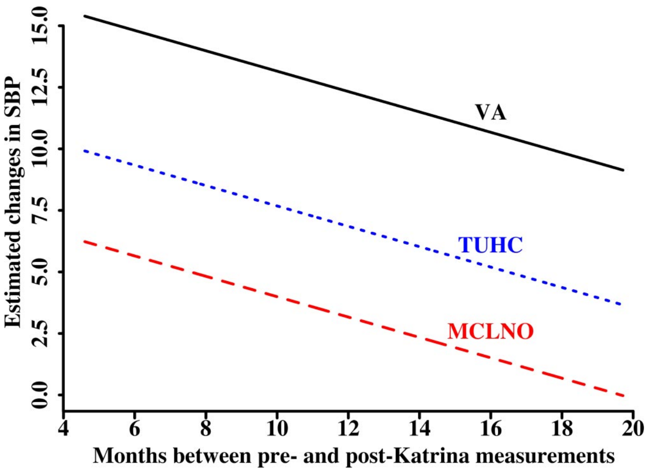

Figure 2—*Model of relationship between change in systolic blood pressure (SBP) and time in patients in three different health systems in New Orleans, before and after Hurricane Katrina.*

CONCLUSIONS — Our data clearly demonstrate that a major disaster had a significant adverse effect on diabetes management that may have a lasting impact on individuals so affected, resulting in both negative health and economic implications. Furthermore, disparities in health, related to socioeconomic status that existed before the disaster, have been exacerbated, with potential long-term consequences.

Very few studies have been carried out on the effect of major disasters on diabetes and its comorbidities (6–19). Published data includes reports on hurricanes within the U.S., but these have been relatively small and short-term studies (20). Studies in Japan after major earthquakes have demonstrated an increase in stress associated with poor glycemic control for up to 1 year (10). High scores on a questionnaire regarding property damage, injuries, and mortality among relatives were taken to indicate increased psychological stresses from the survivors and were associated with increased A1C (10). Similar effects have been reported with hypertension, with ambulatory blood pressure revealing that sympathetic activation is an

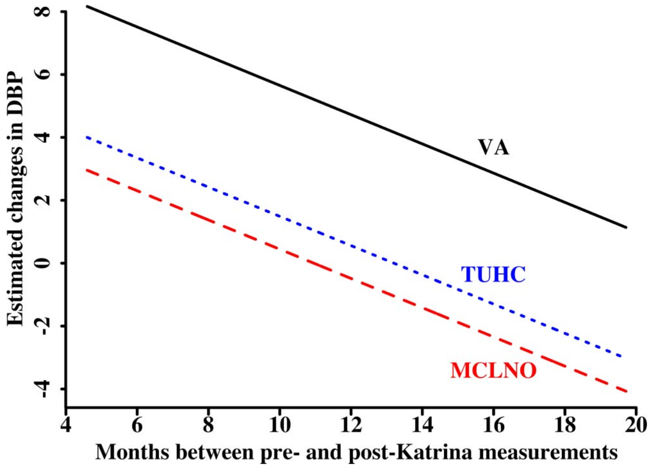

Figure 3—*Model of relationship between change in diastolic blood pressure (DBP) and time in patients in three different health systems in New Orleans, before and after Hurricane Katrina.*

important component of rising blood pressure after life-threatening events and may trigger myocardial infarction (15,19). For example, the war in Croatia led to prolonged stress, impacting cortisol levels and loss of metabolic control in individuals with type 2 diabetes (16).

Patients most severely affected by Hurricane Katrina may have been unable to return to the New Orleans area. However, in systems such as the VA, it is possible to monitor patients pre- and postevent, as they may have been seen in other VA facilities. Unfortunately, in the other systems we were limited to including only those who returned and also had intact predisaster records. Thus, our findings are a conservative estimate of the impact and are likely to not reflect the worst case scenarios (e.g., patients who died or those most seriously affected financially, making return impossible). Our findings can only be extrapolated to the impact on individuals who survive a disaster and who remain/return to the same geographical area.

We have also demonstrated a difference in the time course of these changes in cardiovascular risk factors. For example, blood pressure was highest very shortly after the disaster and gradually declined with time. In contrast, the reverse occurred with A1C, which is not surprising, given that A1C reflects a much longer time period and is more stable than blood pressure. A short and sharp rise in blood pressure has previously been documented in short-term studies after other natural disasters (17), whereas A1C has not been previously tested in such studies.

Our study also demonstrates significant reduction in life expectancy and QALE in all three patient populations. Even though the increase in advance events was not measured in the study, the overall modeled reduction in life expectancy should result from myocardial infarction or cardiovascular diseases, rather than end-stage renal disease, particularly in the setting of a large elevation of blood pressure. Furthermore, these data demonstrate that the disaster led to an increase in lifetime costs related to health care in all three systems.

In diabetes, several simulation models have been used to describe disease progression and estimate the cost effectiveness of interventions (21–25). Because they are not statements of scientific fact, simulation models may be used to

Table 3—*CDM estimates of changes in life expectancy and health care costs per patient related to Hurricane Katrina*

	Effect	SD	*P*	Extrapolated cost (US$)*†	−10% variation (US$)	+10% variation (US$)
MCLNO (20%)						
Life expectancy (year)	−0.301	0.552	<0.0001			
QALE	−0.242	0.431	<0.0001			
Direct cost	3,502	6,391	<0.0001	62,160,699	55,944,629	68,376,769
Indirect cost	1,741	3,250	<0.0001	30,902,849	27,812,564	33,993,134
Total cost	5,243	8,664	<0.0001	93,063,548	83,757,193	102,369,903
TUHC (75%)						
Life expectancy (year)	−0.078	0.455	<0.0001			
QALE	−0.07	0.354	<0.0001			
Direct cost	1,840	5,354	<0.0001	122,475,392	110,227,853	134,722,931
Indirect cost	430	2,682	<0.0001	28,621,967	25,759,770	31,484,163
Total cost	2,270	6,927	<0.0001	151,097,359	135,987,623	166,207,094
VA (5%)						
Life expectancy (year)	−0.264	0.483	<0.0001			
QALE	−1.208	0.371	<0.0001			
Direct cost	2,683	5,423	<0.0001	178,587,759	160,728,983	196,446,535
Indirect cost	1,224	2,850	<0.0001	81,472,761	73,325,485	89,620,037
Total cost	3,907	7,201	<0.0001	260,060,520	234,054,468	286,066,572
Population cost				504,221,426	453,799,283	554,643,569

*Adult population (age ≥18 years): 964,677, estimated for greater New Orleans of seven parishes affected by Hurricane Katrina (Orleans Parish, Jefferson Parish, St. Bernard Parish, St. Tammany Parish, Plaquemines Parish, St. Charles Parish, and St. John the Baptist Parish), Louisiana. Source: http://censtats.census.gov/data/LA. †Prevalence of diabetes in 2006 (Louisiana): 9.2%. Source: http://apps.nccd.cdc.gov/brfss/page.asp?cat=DB&yr=2007&state=LA#DB.

make inferences about future economic, quality-of-life, and health outcomes to provide data for decision making. This advantage is particularly important when an empirical study is logistically infeasible. In the care for diabetes, the health consequences of changes in A1C, lipids, and blood pressure on long-term outcomes in type 2 diabetic patients have been modeled using the CDM (3). That study calculated the projected effects on life expectancy and QALE and total costs of complications of 10% improvements in baseline levels of total cholesterol, HDL cholesterol, systolic blood pressure, A1C, and all four parameters combined. Despite the lack of studies using models to examine loss of control rather than improved control (through interventions being studied), we believe that this model can be easily applied to estimate the impact of the hurricane on long-term outcomes. The CDM is based on clinical trials/studies. This fact be viewed as a potential criticism of the model, as these data sources may not be suitable for every population or simulated setting nor accurately reflect the real-life situation in which factors such as noncompliance and various standards of care may have an influence. Another limitation that relates to the heterogeneity of the study population is that the customized CDM for the present study is not based on person-specific values to compute overall risk. To compute risk, the default CDM uses the UKPDS data, which have a diet run-in period for a population (no previous cardiovascular disease event or any serious diabetes complication). The clinical pathways/transition probabilities should differ across distinctive populations. However, no changes in model transition probability have been customized for the presenting study by only changing the model parameters.

Our study is unique in demonstrating the impact of a disaster in the U.S. on a chronic disease condition that is highly prevalent. The factors presented in this study need to be taken into consideration in disaster planning and in addressing chronic health conditions in the aftermath of a disaster. If appropriate action is not taken, the increase in health care costs could be considerable.

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The content is solely the responsibility of the authors and does not necessarily represent the official views of the Eunice Kennedy Shriver National Institute of Child Health and Human Development, the National Institute of Health, or the U.S. government.

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