

# The impact of natural disasters on medicare costs in U.S. gulf coast states

Jennifer Horney, PhD<sup>a,\*</sup>, Nathanael Rosenheim, PhD<sup>b</sup>, Hongwei Zhao, ScD<sup>c</sup>, Tiffany Radcliff, PhD<sup>d</sup>

## Abstract

Medicare utilization and costs for residents of the U.S. Gulf Coast, who are highly vulnerable to natural disasters, may be impacted by their disaster exposure.

To estimate differences in healthcare utilization by disaster exposure, we calculated Medicare expenditures among residents of U.S. Gulf States and compared them with expenditures among residents of other regions of the U.S.

Panel models were used to calculate changes in overall Medicare expenditures, inpatient expenditures, and home health expenditures for 32,819 Medicare beneficiaries. Individual demographic characteristics were included as predictors of change in expenditures.

Medicare beneficiaries with National Health Interview Survey participation were identified and Part A claims were linked. Federal Emergency Management Agency (FEMA) data was used to determine counties that experienced no, some, high, and extreme hazard exposure. FEMA data was merged with Medicare claims data to create a panel dataset from 2001 to 2007.

Medicare Part A claims for the years 2001 to 2007 were merged with FEMA data related to disasters in each U.S. County. Overall Medicare costs, as well as costs for inpatient and home health care for residents of states located along the U.S. Gulf Coast (Texas, Louisiana, Mississippi, Alabama, and Florida) were compared to costs for residents of the rest of the U.S.

Expenditures among residents of U.S. Gulf States decreased with increased hazard exposure. Decreases in inpatient expenditures persisted in the years following a disaster.

The use of beneficiary-level data highlights the potential for natural hazards to impact health care costs. This study demonstrates the possibility that exposure to more severe disasters may limit access to health care and therefore reduce expenditures. Additional research is needed to determine if there is a substitution of services (e.g., inpatient rehabilitation for home health) in disaster-affected areas during the post-disaster period.

**Abbreviations:** CMS = Centers for Medicare and Medicaid Services, FEMA = Federal Emergency Management Agency, FIPS = Federal Information Processing Standards, NHIS = National Health Interview Survey.

**Keywords:** disasters, medicare, utilization, cost

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<sup>a</sup> Professor, Epidemiology, University of Delaware, 100 Discovery Blvd., Newark, DE, <sup>b</sup> Associate Research Scientist, Hazard Reduction and Recovery Center, 3137 TAMU, College Station, <sup>c</sup> Professor, Epidemiology and Biostatistics, Texas A&M University School of Public Health, 1266 TAMU, College Station, <sup>d</sup> Professor, Health Policy and Management, Texas A&M University School of Public Health, 1266 TAMU, College Station, TX.

\* Correspondence: Jennifer Horney, University of Delaware, 100 Discovery Blvd., Newark, DE 19713 (e-mail: horney@udel.edu).

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## 1. Introduction

The growing proportion of the U.S. population over age 65 are disproportionately vulnerable to the health impacts of natural disasters due to their higher prevalence of hazard zone occupancy, living in less hazard-resistant structures, and lower rates of emergency preparedness.<sup>[1–4]</sup> Few published studies have attempted to characterize the impacts of disasters on older adult's utilization of Medicare, and the associated costs, after disasters. After Hurricane Katrina, physician office visits among Medicare Advantage enrollees in 4 Louisiana Parishes declined 57%, while emergency department visits and inpatient hospitalization rates increased.<sup>[5]</sup> Medicare inpatient claims for fee-for-service beneficiaries over age 65 increased by 4.3% (95% CI: 3.8%, 4.8%) for each 10°F increase in daily mean summer temperature.<sup>[6]</sup> An analysis of county-level Medicare claims showed cost and utilization was higher in counties with more hazard exposure; however, utilization of home health services was lower in counties with more hazard exposure.<sup>[7]</sup>

Changes in utilization of health care services after disasters have been more widely documented among younger populations and Veterans, although both increases and decreases have been noted. Among those working in New Orleans after Hurricane Katrina, only 27% reporting health problems sought medical treatment.<sup>[8]</sup> An assessment of missed ambulatory care appointments in Veterans Affairs clinics following Hurricane Ike showed that disaster-related care disruptions were more frequent in clinics

located in more severely impacted areas.<sup>[9]</sup> However, after the severe hurricane season of 2004, veterans with post-traumatic stress disorder in counties affected by hurricanes reported utilizing 28% more mental health services.<sup>[10]</sup> A better understanding of the utilization of Medicare in regions impacted by disasters is needed to improve disaster planning, response, and recovery.

## 2. Methods

### 2.1. Sample

To quantify the impacts of natural disasters on Medicare costs, we conducted a longitudinal analysis using data from the National Health Interview Survey (NHIS) linked to Medicare claims data from the Centers for Medicare and Medicaid Services (CMS).<sup>[11–13]</sup> The NHIS-CMS linked file included individual-level Medicare Part A claims, summarized by calendar year for matched NHIS survey respondents. The linked data provided demographic information on individual beneficiaries (e.g., age, gender, race, and ethnicity) and county of residence. The NHIS-CMS linked data file was merged with disaster declaration data from the Federal Emergency Management Agency (FEMA) by County and State Federal Information Processing Standards (FIPS) codes.

The panel size changes each year as new individuals become eligible for Medicare or die. To ensure the panel model had adequate data for comparing changes in cost, individuals with less than 4 years of Medicare data were excluded from the sample, leaving approximately 44,800 beneficiaries per year who had between 4 and 7 years of data ( $N=302,625$ ). Approximately 9000 beneficiaries in the sample were residents of U.S. Gulf States, including Texas, Louisiana, Mississippi, Alabama, and Florida ( $N=60,410$ ), a region that is highly vulnerable to natural disasters.

### 2.2. Measures

County-level hazard exposure was defined using FEMA data related to disaster declarations as well as information on the dollar amounts distributed to counties and individuals for disaster response and recovery.<sup>[14–16]</sup> To account for differences in the severity of disasters over the study period, a hazard factor exposure variable was created by conducting a principle component factor analysis using 4 variables available from FEMA, including:

1. the total number of days with major disaster declared,
2. the available public assistance divided by estimated county population,
3. housing assistance dollars approved divided by populations in all designated counties for the related disaster, and
4. other needs assistance dollars approved divided by populations in all designated counties.

Three types of Medicare expenditures were calculated, including overall expenditures, total inpatient expenditures, and total home health expenditures. Expenditure measures are summarized by individual over the calendar year.

### 2.3. Analysis

FEMA data was merged with the linked NHIS-CMS file to create a panel dataset from 2001 to 2007. Descriptive analyses were conducted to explore changes in exposures and outcomes over time. Means, standard errors, and percentages were calculated and ANOVA and Chi-Squared tests were conducted as appropriate. Changes in the 3 cost measures were described using means and

standard errors for each category of the hazard exposure factor variable (e.g., no, some, high, extreme).

Multivariate random-effects models were used to evaluate associations between hazard exposure and cost. Models also included individual-level demographic characteristics for individuals in the sample (e.g., years over age 65, sex, race/ethnicity, education, poverty status recorded in the year of NHIS survey, reason for Medicare eligibility, and recorded death), and year variables to control for trends. Random effects dummy variables included sex (Female=1), main racial background (African-American=1), ethnicity (Hispanic=1), education attainment (no college=1), income below poverty during the year the person responded to the NHIS, and reason for Medicare coverage other than old age or survivor. These explanatory variables did not change for each individual across the 7 years period. The outcome variables were log transformed and all data analyses were conducted using Stata 13 XTREG (College Station, TX). This research was reviewed and approved by the Institutional Review Board of Texas A&M University (IRB2015-0811M).

## 3. Results

### 3.1. Hazard exposure factor

The hazard exposure factor was mean-centered and ranged from  $-0.16$  in counties with no exposure to disaster to  $9.08$  (standard deviation  $6.18$ ) in counties with extreme disaster exposure. Counties with no exposure have no days of major disaster declaration and no associated costs (Table 1). Counties with some exposure experienced an average of 32 days of major disaster declaration and received \$16.63 in public assistance, \$3.07 in housing assistance, and \$1.29 in individual assistance per capita. High exposure counties experienced major disaster declarations for an average of 130 days and received per \$204.45 in public assistance, \$23.36 in housing assistance, and \$23.89 in individual assistance per capita. Extreme exposure counties experienced an average of 95 days of major disaster declaration and received \$963.74 of public assistance, \$491.59 in housing assistance, and \$206.05 in individual assistance per capita.

During the study period, only residents of U.S. Gulf Coast states experienced high or extreme hazard exposure (Fig. 1). The largest concentration of extreme hazard exposure was during 2004 (Hurricanes Charley, Frances, Ivan, and Jeanne) and 2005 (Hurricanes Katrina, Rita, and Wilma). In 2004, 19% of Gulf residents had high hazard exposure and 18% had extreme hazard exposure. In 2005, 10% had extreme hazard exposure. In other regions, between 43% and 84% of residents had no hazard exposure and between 16% and 57% had some hazard exposure.

### 3.2. Descriptive analyses

There were no substantive differences in population demographics over the 7-year period. The average years over age 65 was 8.5 in 2001 and 14 in 2007, reflecting the aging of the panel. More than half (56%) of the sample was female, 10% was African-American, 10% was Hispanic, 64% had no college, and 12% had income below poverty in the year of their NHIS survey. Individuals with higher levels of hazard exposure generally had higher total Medicare expenditures, with those having extreme

**Table 1**  
**Hazard exposure at the county level, 2001–2007.**

	Mean (standard deviation) No Hazard Exposure N = 14,873 (68.4%)	Mean (standard deviation) Some Hazard Exposure N = 6,662 (30.6%)	Mean (standard deviation) High Hazard Exposure N = 51 (0.2%)	Mean (standard deviation) Extreme Hazard Exposure N = 172 (0.8%)	Mean (standard deviation) Total N = 21,758
Hazard exposure factor	−0.16 (0.00)	0.11 (0.27)	1.44 (0.30)	9.08 (6.18)	0.00 (1.00)
Total days with major disaster declared	0.00 (0.00)	32.35 (39.30)	129.65 (36.43)	95.13 (54.34)	10.96 (28.47)
Total available public assistance divided By estimated county population	0.00 (0.00)	16.63 (60.48)	205.45 (385.15)	963.74 (4,319.97)	13.19 (394.32)
Housing assistance dollars divided by populations in all designated counties	0.00 (0.00)	3.07 (7.10)	23.36 (8.37)	491.59 (362.27)	4.88 (54.20)
Other needs assistance dollars divided by populations in all designated	0.00 (0.00)	1.29 (2.97)	23.89 (9.44)	206.05 (128.70)	2.08 (21.59)

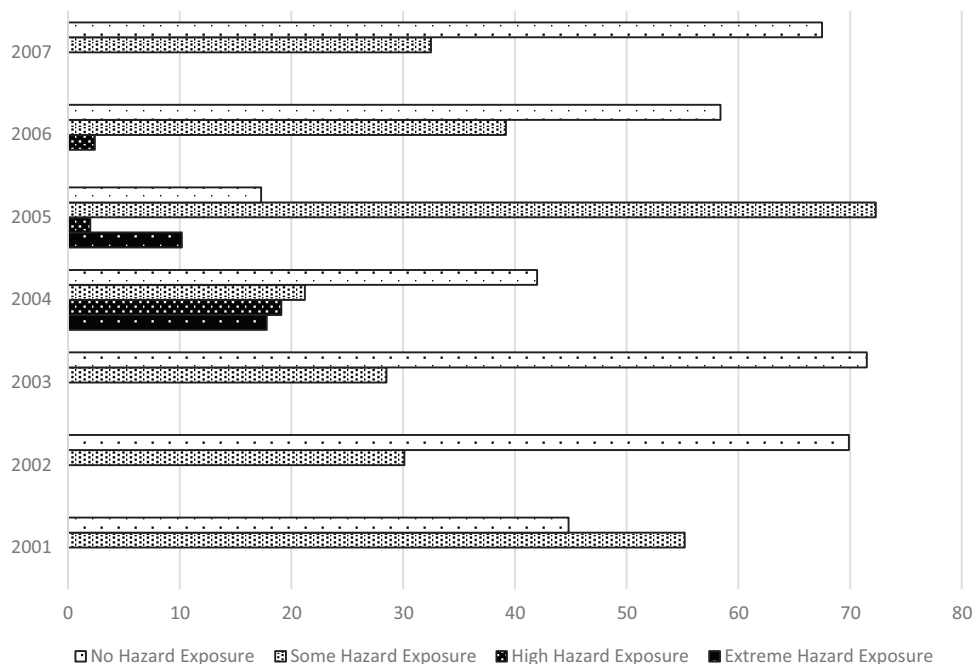
Federal Emergency Management Agency.

hazard exposure having the highest total expenditures (Table 2). However, inpatient expenditures for the high exposure group were lower than expenditures for those with no, some, or extreme exposure and home health expenditures were highest among the group with high exposure and second highest among the group with extreme exposure.

Residents of Gulf States had significantly higher total Medicare expenditures (\$964.08) and home health care expenditures than residents of non-Gulf States (\$373.90) (Table 3). However, residents of Gulf States did not have statistically significant increases in inpatient expenditures than residents of non-Gulf States (\$88.14). U.S. Gulf State residents were slightly younger, more likely to be African–American, Hispanic, have no college education, live below poverty, and have coverage for reasons other than old age or survivorship compared to residents of non-Gulf States.

**3.3. Multivariate modeling**

Table 4 summarizes the results for the random-effects model of Medicare expenditures for both Gulf and non-Gulf States. The outcome variables are log transformed, so coefficients are semi-elastic and can be interpreted as a percent change in the outcome given a unit change in the independent variable. In most categories, the control variables (e.g., age, sex, race, ethnicity, and income) had consistent relationships in both Gulf and non-Gulf States for all three expenditure categories. Race and ethnicity had larger effects on total and home health expenditures for Gulf State residents than residents of the rest of the U.S. For U.S. Gulf State residents, being African–American or Hispanic had a negative relationship with inpatient expenditures when compared to the rest of the U.S., whereas African–American race and Hispanic ethnicity had a positive relationship with home health expenditures.



**Figure 1.** Hazard Exposure of Medicare Beneficiaries (%), U.S. Gulf States. National Health Interview Survey/Centers for Medicare and Medicaid Services Linked Data merged with Federal Emergency Management Agency data, 2001 to 2007.

**Table 2**  
Descriptive statistics by hazard exposure factor.

	None (N = 182,085)	Some (N = 115,521)	High (N = 1,925)	Extreme (N = 2,593)	Total (N = 302,484)
Total medicare expenditures, \$ Mean (standard deviation)	\$7,490.24 (15,099.04)	\$7,393.28 (16,873.94)	\$6,807.05 (16,733.00)	\$8,182.50 (17,160.22)	\$7,421.30 (16,783.84)
Inpatient expenditures, \$ Mean (standard deviation)	\$2,895.60 (8,762.68)	\$2,904.27 (10,396.20)	\$2,153.03 (8,153.23)	\$2,827.52 (9,782.50)	\$2,866.04 (10,178.97)
Home health expenditures, \$ mean (standard deviation)	\$257.73 (1,262.71)	\$360.58 (1,832.10)	\$629.56 (4,081.18)	\$525.26 (2,253.26)	\$376.13 (1,985.83)
Years over age 65 Mean (standard deviation)	11.41 years (6.63)	11.11 years (6.42)	10.99 years (6.38)	10.72 years (6.47)	11.1 years (6.43)
Female, %	55.0%	57.0%	57.0%	54.0%	56.0%
African-American, %	7.0%	10.0%	9.0%	17.0%	10.0%
Hispanic, %	7.0%	9.0%	42.0%	4.0%	10.0%
No College, %	67.0%	64.0%	67.0%	61.0%	64.0%
Below poverty (NHIS year), %	13.0%	12.0%	17.0%	13.0%	12.0%
Coverage other than old age or survivor, %	14.0%	12.0%	12.0%	15.0%	12.0%
Recorded death, %	5.0%	3.0%	2.0%	3.0%	3.0%

National Health Interview Survey/Centers for Medicare and Medicaid Services linked data merged with Federal Emergency Management Agency data, 2001 to 2007.

For those with some hazard exposure during the same year, the relationship between hazard exposure and expenditures was positive for total expenditures and the expenditure amount was similar for residents of non-Gulf and Gulf States. The effect of high hazard exposure during the same year on all types of expenditures was negative. For Gulf States, high hazard exposure was related to a 20% decrease in total Part A Medicare expenditures, a 26% decrease in inpatient expenditures, and a 43% decrease in home health care expenditures. Extreme hazard exposure was associated with a 2% decrease in total expenditures, a 27% decrease in inpatient expenditures, and a 23% decrease in home health care expenditures. High hazard exposure

in the previous year had a negative relationship with both total expenditures and inpatient expenditures.

#### 4. Discussion

It has been recognized in the disaster research literature that the elderly are disproportionately impacted by disasters; however, these impacts have been difficult to quantify across different disaster types and locations.<sup>[17–22]</sup> To better quantify the impacts of disasters on those over age 65, we assessed differences in Medicare expenditures over a seven year period based on hazard exposure and region.

**Table 3**  
Comparison of mean and standard deviation of independent variables with Analysis of Variance differences between U.S. Gulf Residents and Non-Gulf Residents.

	All observations (N = 302, 625) Mean (Standard Deviation)	Comparison group non-Gulf residents Mean (95% CI) <sup>†</sup> (N = 241,718)	<sup>‡</sup> Gulf residents difference from comparison group Mean (95% CI) <sup>†</sup> (N = 60,410)	Variance explained by Gulf residence (R <sup>2</sup> )
Total medicare expenditures, \$	\$7,421.29 (\$16,783.84)	\$7,255.11 (7,188.17,7,322.05)	\$964.08 <sup>***</sup> (814.26,1,113.91)	0.0005
Inpatient expenditures, \$	\$2,866.04 (\$10,178.97)	\$2,859.74 (2,819.15,2,900.34)	\$88.14 (−2.73,179.01)	0.0000
Home health care expenditures, \$	\$376.13 (\$1985.83)	\$301.29 (293.48,309.10)	\$373.90 <sup>***</sup> (356.41,391.39)	0.0058
Age over 65, years	11.10 years (6.43)	11.33 years (11.31,11.35)	−.53 <sup>***</sup> years (−.59,−0.46)	0.0011
Female, %	0.56 (0.50)	0.57 (0.56,0.57)	0.002 (−0.002,0.007)	0.0000
African-American, %	0.10 (0.30)	0.09 (0.091,0.093)	.05 <sup>***</sup> (.045,.050)	0.0040
Hispanic, %	0.10 (0.30)	0.06 (0.063,0.065)	.19 <sup>***</sup> (.18,.19)	0.0601
No College, %	0.64 (0.48)	0.64 (0.642,0.645)	.02 <sup>***</sup> (.019,.028)	0.0004
Below poverty, (NHIS year), %	0.12 (0.33)	0.11 (0.106,0.110)	.09 <sup>***</sup> (.084,.091)	0.0113
Coverage other than old age or survivor, %	0.12 (0.33)	0.114 (0.113,0.116)	.02 <sup>***</sup> (.015,.021)	0.0005
Recorded Death, %	0.03 (0.18)	0.03 (0.032,0.033)	−0.001 (−0.0029,0.0003)	0.0000

\* P < .05.

\*\* P < .01.

\*\*\* P < .001.

<sup>†</sup> 95% confidence interval.

<sup>‡</sup> Gulf residents refers to residents residing in Texas, Louisiana, Mississippi, Alabama, and Florida.

National Health Interview Survey/Centers for Medicare and Medicaid Services linked data merged with Federal Emergency Management Agency data, 2001 to 2007.

**Table 4**  
**Random-Effects Model results for total expenditures, total inpatient expenditures, and total home health expenditures model using all covariates for Gulf residents and non-Gulf residents, 2001 to 2007.**

	Total expenditures		Inpatient expenditures		Home Health Care Expenditures	
	Gulf residents	Non Gulf residents	Gulf residents	Non Gulf residents	Gulf Residents	Non Gulf Residents
Age over 65 (years)	.04*** (.04,.05)	.05*** (.04,.05)	.04*** (.03,0.04)	.03*** (.03,.04)	0.06*** (0.05,0.08)	0.03*** (0.02,0.03)
Female	.29*** (.19,0.39)	.18*** (.13,.23)	0 (-0.11,0.12)	-0.01 (-0.07,0.05)	0.22** (0.07,0.37)	0.14*** (0.07,0.21)
African-American	-.68*** (-.83,-.52)	-.18*** (-.26,-.09)	-.21* (-.4,-.03)	.32*** (.22,0.42)	0.65*** (0.44,0.87)	0.43*** (0.32,0.54)
Hispanic	-.53*** (-.66,-.39)	-.43*** (-.54,-.32)	-.20* (-.36,-.05)	0.07 (-0.06,0.20)	0.65*** (0.46,0.84)	0.25*** (0.10,0.40)
No College	-.16** (-.27,-.04)	-.16*** (-.21,-.10)	.11 (-0.02,.25)	.13*** (.07,.19)	0.13 (-0.04,0.3)	0.04 (-0.03,0.12)
Below poverty (NHIS year)	.50*** (.36,.64)	.11*** (0.03,0.20)	.26*** (0.1,0.41)	.17*** (.07,.26)	0.21* (0.03,0.39)	0.14*** (0.04,0.24)
Coverage other than Old age or survivor	.72*** (.57,.87)	.77*** (0.69,0.85)	.91*** (.74,1.08)	.83*** (.74,.92)	0.56*** (0.35,0.76)	0.58*** (0.47,0.68)
Recorded death	1.25*** (1.14,1.37)	1.20*** (1.14,1.26)	4.00*** (3.77,4.23)	3.85*** (3.73,3.97)	0.88*** (0.64,1.13)	1.21*** (1.08,1.34)
Some hazard exposure	.06* (.01,.11)	.06*** (.04,.09)	0.02 (-0.09,0.14)	.04 (-.02,.09)	0.07 (-0.06,0.2)	0.06 (-0.01,0.13)
High hazard exposure	-.20** (-.33,-.06)		-0.26 (-0.58,0.07)		-0.43* (-0.8,-0.06)	
Extreme hazard exposure	-.02 (-.13,.09)		-.27* (-.53,-.01)		-0.23 (-0.53,0.06)	
Some hazard exposure in previous year	.06* (.01,.11)	.04*** (.02,.07)	0.06 (-0.06,0.17)	0.05 (-0.01,0.10)	0.17** (0.04,0.3)	0.08* (0.01,0.15)
High hazard exposure in previous year	-.34*** (-.47,-.2)		-.64*** (-.96,-.31)		0.03 (-0.35,0.41)	
Extreme hazard exposure in previous year	0.03 (-0.08,0.14)		-0.15 (-0.42,0.11)		0 (-0.31,0.31)	
2002	0.00 (0.00,0.00)	0 (0.00,0.00)	0 (0,0)	0 (0.00,0.00)	0 (0,0)	0 (0.00,0.00)
2003	.27*** (.19,.33)	.19*** (.15,.22)	.21* (.05,.38)	.18 v (.08,.27)	0.45*** (0.26,0.64)	0.23*** (0.12,0.34)
2004	.44*** (.37,.52)	.33*** (.29,.36)	.40*** (.21,.59)	.33*** (.23,.42)	0.92*** (0.71,1.13)	0.51*** (0.39,0.62)
2005	.48*** (.40,.57)	.39*** (.35,.43)	.60*** (.4,.8)	.52*** (.43,.61)	1.24*** (1.01,1.47)	0.77*** (0.66,0.89)
2006	.35*** (.27,.42)	.32*** (.28,.36)	.54*** (.36,.73)	.54*** (.44,.63)	1.64*** (1.43,1.84)	0.89*** (0.78,1.01)
2007	.29*** (.21,.37)	.25*** (.21,.29)	.60*** (.42,.79)	.72*** (.62,.82)	2.09*** (1.88,2.3)	1.16*** (1.04,1.28)
Constant	6.45*** (6.31,6.59)	6.28*** (6.21,6.35)	1.95*** (1.75,2.15)	1.82*** (1.72,1.92)	0.13 (-0.12,0.38)	0.82*** (0.70,0.95)
Observations	39,031	144,207	26,659	94,611	16,056	44,710
Within R <sup>2</sup>	0.026	0.025	0.042	0.041	0.070	0.030
Between R <sup>2</sup>	0.078	0.062	0.177	0.163	0.058	0.050
Overall R <sup>2</sup>	0.051	0.041	0.065	0.061	0.069	0.034

n95% confidence intervals in parentheses.

\*P < .05, \*\*P < .01, \*\*\*P < .001.

\*\* Gulf residents refers to elderly residents residing in Texas, Louisiana, Mississippi, Alabama, and Florida.

National Health Interview Survey/Centers for Medicare and Medicaid Services linked data merged with Federal Emergency Management Agency data, 2001 to 2007.

Similar to prior studies, our findings were mixed; the relationship between both disaster severity and region of residence and Medicare expenditures was inconsistent. When considering the entire U.S. population, total expenditures generally increased with disaster severity, with total expenditures higher for those with extreme hazard exposure. However, inpatient expenditures were lower for those with high hazard exposure, while home health expenditures were highest for those with high hazard exposure. This could reflect substitution (e.g., home health for inpatient rehabilitation in a high hazard exposure situation) or delay (e.g., postponement of care due to evacuation or difficulty travelling) of services after a disaster. The impact of some hazard exposure was relatively consistent across the U.S. However, in U.S. Gulf States, the only region with high and extreme hazard exposure during the study period, expenditures were between 20% and 45% lower during the year with the disaster exposure and 34% to 64% lower in the year following the disaster exposure. This likely reflects to some extent a healthcare infrastructure and provider base that were devastated after severe storms like Hurricane Katrina in 2005.<sup>18</sup>

The quantification of the impacts of disasters on Medicare costs may provide insights to improve pre-disaster planning and preparedness, as well as post-disaster response of the Medicare system. However, this study has several important limitations. Using restricted access individual-level data required the review and approval of NCHS, which potentially extended the time necessary to conduct this study. Since its inception, additional

years of linked data have become available, but we were unable to add this data without a revised NCHS proposal. Working with this data required access to a Federal Census Data Research Center and the acquisition of Special Sworn Status by the research team. A strength of this research was the use of the hazard exposure variable, which incorporates additional FEMA data to account for the size, scope, and potential impact of disasters. This new hazard exposure variable can be reproduced and may help to clarify the interpretation of correlations between hazard exposure intensity and Medicare utilization and costs within the random effects model.

### Author contribution

JAH obtained funding, conceived the analysis, and wrote the paper; NR conducted the analysis and edited the paper; HZ designed the analysis and edited the paper; TR designed the analysis and edited the paper.

Jennifer Horney orcid: 0000-0003-3060-0894.

### References

- [1] Ngo EB. When disasters and age collide: reviewing vulnerability of the elderly. *Nat Hazards Rev* 2001;2:80-9.
- [2] National Research Council. *Facing Hazards and Disasters: Understanding Human Dimensions*. Chapter 2: Societal Changes Influencing the Context of Research (pp. 41-70). Washington, DC: The National Academies Press. doi: 10.17226/11671.

- [3] Jia Z, Tian W, Liu W, et al. Are the elderly more vulnerable to psychological impact of natural disaster? A population-based survey of adult survivors of the 2008 Sichuan earthquake. *BMC Public Health* 2010;10:172.
- [4] Behr JG, Diaz R. Disparate health implications stemming from the propensity of elderly and medically fragile populations to shelter in place during severe storm events. *J Public Health Manag Pract* 2013;19:S55–62.
- [5] Burton LC, Skinner EA, Uscher-Pines L, et al. Health of Medicare Advantage plan enrollees at 1 year after Hurricane Katrina. *Am J Manag Care* 2009;15:13–22.
- [6] Anderson GB, Dominici F, Wang Y, et al. Heat-related emergency hospitalizations for respiratory diseases in the Medicare population. *Am J Respir Crit Care Med* 2013;187:1098–103.
- [7] Rosenheim N, Grabich S, Horney JA. Disaster impacts on cost and utilization of Medicare. *BMC Health Serv Res* 2018;18:89.
- [8] Rudowitz R, Rowland D, Shartzer A. Health care in New Orleans before and after Hurricane Katrina. *Health Aff* 2006;25:w393–406.
- [9] Radcliff TA, Chu K, Der-Martirosian C, et al. A model for measuring ambulatory access to care recovery after disasters. *J Am Board Fam Med* 2018;31:252–9.
- [10] Frahm KA, Barnett SD, Brown LM, et al. Posttraumatic stress disorder and use of psychiatric and alcohol related services: the effect of the 2004–2005 Florida hurricane seasons on veterans. *Community Ment Health J* 2013;49:636–42.
- [11] Blewett LA, Drew JA, Griffin R, et al. IPUMS Health Surveys: National Health Interview Survey, Version 6. 2. Minneapolis: University of Minnesota; 2016. <http://doi.org/10.18128/D070.V6.2>. Available at: <http://www.nhis.ipums.org> [accessed July 15, 2018]
- [12] National Center for Health Statistics 2014 Public-Use NCHS-CMS Medicare Feasibility Files. Available at: <https://www.cdc.gov/nchs/data-linkage/medicare-feasibility.htm> [accessed May 28, 2018].
- [13] National Center for Health Statistics 2016 Data access: NCHS Data linked to CMS Medicare enrollment and claims files [on-line]. Available at [http://www.cdc.gov/nchs/data\\_access/data\\_linkage/cms\\_medicare.htm](http://www.cdc.gov/nchs/data_access/data_linkage/cms_medicare.htm) [Accessed May 15, 2018].
- [14] Federal Emergency Management Agency. 2014a. “FEMA Disaster Declarations Summary - Open Government Dataset”. Available at: <http://www.fema.gov/media-library/assets/documents/28318> [accessed July 8, 2018].
- [15] Federal Emergency Management Agency. 2014b. “FEMA Public Assistance Funded Projects Detail - Open Government Initiative”. Available at: <http://www.fema.gov/media-library/assets/documents/28331> [accessed July 8, 2018].
- [16] Federal Emergency Management Agency. 2014c. “FEMA Disaster Declarations by Year”. Available at: <http://www.fema.gov/disasters/grid/year> [accessed July 8, 2018].
- [17] Super N, Biles B. Displaced by Hurricane Katrina: Issues and Options for Medicare Beneficiaries. Henry J. XXX;Kaiser Family Foundation Medicare Policy Brief, Retrieved from: <https://www.kff.org/medicare/issue-brief/displaced-by-hurricane-katrina-issues-and-options> [accessed April 6, 2015]. Published October 31, 2005
- [18] Mokdad AH, Mensah GA, Posner SF, et al. When chronic conditions become acute: prevention and control of chronic diseases and adverse health outcomes during natural disasters. *Prev Chronic Dis* 2005;2 (SA04):71.
- [19] Ferdinand KC. The Hurricane Katrina Disaster: focus on the hypertensive patient. *J Clin Hypertens* 2005;7:679–80.
- [20] Knowles RM, Garrison B. Planning for elderly in natural disasters. *Disaster Recov J* 2006;19:1904–7.
- [21] Kessler RC. Hurricane Katrina’s impact on the care of survivors with chronic medical conditions. *J Gen Intern Med* 2007;22: 1225–30.
- [22] Krousel-Wood MA, Islam T, Muntner P, et al. Medication adherence in older clinic patients with hypertension after Hurricane Katrina: implications for clinical practice and disaster management. *Am J Med Sci* 2008;336:99–104.