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Using Appendiceal Perforation Rates to Measure Impact of a Disaster on Healthcare System Effectiveness

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Abstract

Objectives—To understand baseline inequities in appendiceal perforation rates and the impact of hurricane destruction on the healthcare system with respect to perforation rates and racial disparities.

Methods—We used claims data extracted from Medicaid Analytic Extract files to identify appendicitis diagnoses in children and adolescents based on *International Classification of Diseases-9* codes and appendectomy procedures based on Current Procedural Terminology codes in the hurricane-affected states of Mississippi and Louisiana. County-level summary data obtained from 2005 Area Resource Files were used to determine high and low hurricane-affected areas. We estimated logistic regression models, mutually adjusting for race, sex, and age, to examine disparities and mixed logistic regression models to determine whether county-level effects contributed to perforation rates.

Results—There were nine counties in the high-impact area and 133 counties in the low-impact area. Living in the high- or low-impact area was not associated with a statistically different rate of perforation before or after Hurricane Katrina; however, living in the high-impact area was associated with a change from a lower risk (odds ratio [OR] 0.62) of perforation prehurricane to a higher risk (OR 1.14) posthurricane compared with those living in the low-impact areas. African Americans had statistically higher perforation rates than whites in the high-impact areas both before (OR 1.46) and after (OR 1.71) Hurricane Katrina.

Conclusions—Health professionals and hospital systems were able to maintain effective levels of care before and after Hurricane Katrina; however, perforation rates in African Americans suggest ongoing racial disparities during disasters.

Keywords

appendiceal perforation rates; healthcare-accessing barriers; healthcare infrastructure; healthcare system effectiveness

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Natural disasters destroy healthcare infrastructure and capacity just when they are needed most. In August 2005, Hurricane Katrina displaced more than 1.5 million residents in the Gulf Coast region and destroyed >90,000 mi^2 of property, including >300,000 homes.[1] Many rural and urban healthcare facilities also were destroyed,[2] affecting a region that has demonstrated some of the greatest poverty and worst health outcomes in the United States.[3–5]

Barriers to accessing health care after Hurricane Katrina have been widely documented.[6,7] A report by the Mississippi State Department of Health showed that 36% of the primary care clinics in the most damaged lower 6 counties were closed or destroyed, all 14 area hospitals were damaged, and 3 hospitals were closed.[8] In 2006, Springgate et al conducted a community assessment in New Orleans and revealed continuous healthcare access challenges and unmet needs of vulnerable populations.[9] Fifty percent of the respondents with a history of chronic disease to a 2008 Harvard School of Public Health study stated that they “would need medical care and would not be able to get it” if another disaster occurred.[10]

The disaster did not affect all segments of the community equally. African Americans were significantly more likely than other races to experience the loss of friends, family, and property.[11] Davis et al found that few studies focused on the specific impact of disasters on preexisting health disparities.[12]

Studies of the long-term impact on health outcomes have been difficult, in part because of posthurricane migration and other dynamic changes in the population. One measure of healthcare system access and effectiveness that is not dependent on population denominators is appendiceal perforation rates. Appendicitis is the most common reason for abdominal surgery in children.[12a] Temple et al showed that the time delay between the onset of appendicitis symptoms and simple appendectomy was 22 hours but 57 hours when perforation of the appendix occurred.[13] Disparities in perforation rates may reflect regional differences, with higher perforation rates reported in rural versus urban settings[14]; however, racial-ethnic differences that persist even after controlling for insurance status and neighborhood poverty are more difficult to explain.[15]

Barriers to healthcare access have been shown after other types of disasters, although few studies have examined in detail the impact of Hurricane Katrina on health equity and access to the healthcare system after the disaster.[16] We undertook the present study to understand baseline inequities in appendiceal perforation rates and the impact of hurricane destruction of healthcare system capacity on perforation rates and racial disparities in these rates.

Methods

Data Source

Our study used claims data extracted from the 2004–2007 Medicaid Analytic Extract (MAX) files obtained from the Centers for Medicare & Medicaid Services (CMS)[17] and county-level summary data obtained from the 2005 Area Resource File developed by the US Department of Health and Human Services Health Resources and Services

Administration.[18] The study received institutional review board approval from the Morehouse College School of Medicine. MAX files are compiled by CMS from claims and eligibility data submitted by states to the CMS Medicaid Statistical Information System for production of required state-level reports and are made available to researchers under specific data use agreements to protect client confidentiality. Data fields and data dictionary are standardized from state to state, although differences in reimbursement rates, billing practices, and fiscal intermediary procedures may affect the ability to capture specific procedures.

MAX files represent final action, paid claims for a single calendar year, based on date of service rather than on billing date or date of payment. Data in the MAX files are divided into one personal summary or enrollment file (one record per unduplicated person) and four claims files, including outpatient/other, inpatient, long-term care, and drug files, in which there is one record per billing claim or encounter. Data files are stored securely and confidentially.

Study Population

From the personal summary file we identified all of the children and adolescents (ages 0–18 years) residing in Louisiana and Mississippi from 2004 to 2007, and all of those with both a primary diagnosis of appendicitis for an inpatient admission (inpatient file) and a claim for an appendectomy procedure (outpatient/other file) were included in the sample. Louisiana and Mississippi were sampled because medical services were most affected by Hurricane Katrina. The time period chosen would allow for a comparison in perforation rates before and after the hurricane.

Outcome Variable

The rate of perforated appendix observed during appendectomy was the outcome of interest. The Medicaid MAX inpatient file was used to obtain data on appendectomy procedures, and appendectomy was defined as any billing with *International Classification of Diseases-9* procedure codes[19] 470.1 and 470.9. Appendicitis with perforation was obtained using *International Classification of Diseases-9* diagnosis codes 540.0 and 540.1 taken from both the inpatient file and the outpatient/other (outpatient/other). The outpatient/other file includes all claims for physicians' fees, including surgical procedures.

Main Predictor (Independent Variable)

The main predictor of interest was residence in a county affected by Hurricane Katrina. We classified counties based on a report by the Federal Emergency Management Agency that identified counties in Alabama, Mississippi, and Louisiana as having at least 2% or 10% storm damage to buildings and structures. We chose to compare counties with at least 10% damage (high impact) rather than those with <10% damage (low impact).

Other Predictors/Confounders

Patient-level data included information from the Medicaid claims for the following variables: age, race-ethnicity, sex, and county of residence. County-level data also were examined. The counties were classified by whether they were a Metropolitan Statistical Area

(MSA) using the 2003 Rural Urban Continuum codes (codes 1–3 as urban and codes 4–7 as rural) obtained from the US Department of Agriculture. Variables obtained from the Area Resource File provided the following county level totals: percentage of African Americans, percentage of individuals 0 to 17 years old living in poverty, number of hospitals with an emergency department (ED), number of hospitals with surgical units, and number of surgeons per 100,000 population.

Statistical Analysis

We used SAS version 9.1 (SAS Institute, Cary, NC) for all of the analyses we performed for the period before the hurricane (August 25, 2005) and after. Chi square tests were used to test for pre- and posthurricane differences in the rate of perforated appendix observed during appendectomy among different demographic groups. We estimated logistic regression models mutually adjusting for race, sex, and age to examine whether disparities existed in both areas pre- and posthurricane. To determine whether county-level effects may be contributing to perforation rates, we estimated a two-level (level 1: claims, level 2: county) mixed logistic regression models using Proc Glimmix (SAS Institute) with perforated appendix as the outcome variable. The model estimated the main effects for the covariates. Because all of the hurricane-affected counties were in an MSA and there was colinearity of MSA with population density, the MSA variable was excluded from the models.

Results

Characteristics of the counties and appendectomy claims in the hurricane-affected (high impact) and non–hurricane-affected (low impact) areas are presented in Table 1. There were 9 high-impact counties and 133 low-impact counties. All nine counties (100%) in the high-impact area were in an MSA, whereas only 27% of the counties in the low-impact area were in an MSA; therefore, population density was significantly higher in the high-impact counties. Low-impact counties had a higher percentage of children living in poverty (33.12% vs 24.51%) and African American population (22.69% vs 14.06%) on average than high-impact counties; on average, the low-impact counties also had fewer hospitals with an ED (0.98 vs 1.79) or surgical department (0.66 vs 1.44) and fewer surgeons per 100,000 population (5.9 vs 11.1). There were 532 Medicaid appendectomy claims among the residents of high-impact counties but 2700 among residents of low-impact counties. Despite contextual differences at the county level, the age, sex, and race distribution of Medicaid appendectomy claims did not differ between the high-impact and low-impact counties.

Table 2 presents rates of perforation and odds ratios (ORs) for age, race, and sex before and after the hurricane in the high-and the low-impact counties. African Americans, young children, and boys/men had statistically (chi square $P < 0.05$) higher rates of rupture in the combined study area for the entire study period. The chi square tests conducted to determine whether there were significant differences in rupture percentage pre- and posthurricane within each area did not reveal any significant differences in the race, age, or sex groups or in the total study population. African Americans had statistically higher rates of perforation than whites in both the high-impact (pre OR 2.16 [95% confidence interval {CI} 1.23–3.80], post OR 2.46 [95% CI 1.41–4.28]) and the low-impact counties (pre OR 1.46 [95% CI 1.14–

1.87], post OR 1.71 [95% CI 1.38–2.12]). This African American–white disparity in rates did not change substantially after the hurricane in either the high-or low-impact counties. Only before the hurricane in the low-impact counties did those in the Other race category have a higher rate than whites at a statistically significant level (OR 2.43, 95% CI 1.15–5.18). After the hurricane in the high-impact area, boys/men had a greater rate of rupture than girls/women (OR 1.99, 95% CI 1.16–3.42).

The results of the multilevel logistic regression model results are presented in Table 3. Living in a high-impact area was not associated with a statistically different rate of perforation before or after Hurricane Katrina compared with living in a low-impact area; however, the direction of association did change from those living in a high-impact area being at a lower risk (OR 0.62) before the hurricane to being at a higher risk (OR 1.14) after. None of the county-level measures were significantly related to rate of perforation. Young children (OR 1.46, 95% CI 1.15–1.84) and African American race (OR 1.53, 95% CI 1.18–1.98) and children of another race (OR 2.14, 95% CI 1.13–4.07) were at greater risk of appendiceal perforation before the hurricane. After Hurricane Katrina, African American race was associated with an increased risk of perforation compared with white race (OR 1.82, 95% CI 1.44–2.30).

Discussion

Our findings show that Hurricane Katrina had its greatest impact on the coastal and more densely populated metropolitan areas of Mississippi and Louisiana, whereas mostly rural, less densely populated areas were not as greatly affected. We considered the high-impact counties to have better prehurricane access to health care because of a higher concentration of EDs and surgeons. After Hurricane Katrina, this access to health care changed significantly. Most health facilities in the hurricane-affected counties were damaged and unable to provide any care or the same level of care, which meant that patients with surgical emergencies were diverted to facilities in less-affected or non–hurricane-affected counties and surrounding states.[6,20] These dramatic shifts in population denominators require outcome metrics that are not tied to population-based rates. Because nearly all cases of appendicitis eventually present to hospitals, the proportion that progress to perforation can be used as an indicator of healthcare system effectiveness independent of shifting populations.[21,22]

The finding that residents in the hurricane-affected and non–hurricane-affected counties showed no significant difference in perforation rates before and after the hurricane is somewhat surprising, given the disruptive impact on the healthcare system infrastructure, staffing, and demand. For example, Smith and Graffeo showed that after Hurricane Isabel, there was a significant increase in ED volume exacerbated by communication failures, inability to access on-call personnel, and provider and nursing understaffing.[23] An increased volume of minor injuries and the resulting ED congestion created new obstacles for the efficient care of people with more serious medical and surgical emergencies, including appendicitis. Despite this, our findings are consistent with studies showing no change in overall child mortality pre- and post-Katrina and studies demonstrating an actual decline in both neonatal and postneonatal infant mortality rates.[24] We offer the outmigration of higher-

risk mothers as one potential explanation for these rate trends, reinforcing our decision to use appendiceal perforation rates rather than using any health indicators that would require an accurate population-based denominator.

Previous studies have demonstrated the utility of administrative claims data to monitor appendiceal perforation rates. A study of the 2000 Kids Inpatient Database showed national perforation rates of 29% for white, non-Hispanic children 4 to 18 years old, but 36% in each of three nonwhite racial-ethnic groups (African American, Hispanic, and Asian), with clear gradations by neighborhood median household incomes (29% perforation rates for upper-income zip codes increasing to 38% for children from low-income neighborhoods). Similar disparities were noted for public insurance (37% perforation rates) versus private insurance (29%). Even after controlling for biological, social, and health system factors,[25] similar national studies of pediatric inpatient admissions from 1997–2002 showed significant disparities in appendiceal perforation rates by race (higher risk of perforation for Asian and African American) and by insurance status (higher risk of perforation for uninsured and public insurance).[26] Canadian studies have found socioeconomic and rural–urban disparities in pediatric appendiceal perforation rates despite universal health insurance coverage.[27]

Explaining disparities in appendiceal perforation rates is beyond the scope of the present study, but the evidence to date points to patient-level (poverty, education, and cultural factors) and system-level factors (lack of insurance or public insurance coverage, hospital size and volume, rural–urban context); however, these disparities do not appear to be the inevitable result of social determinants. Elimination of access barriers by treating children within the same system of care appeared to eliminate racial and socioeconomic disparities in perforation rates, at least within the southern California Kaiser Permanente hospital system for a 10-year period, 1998–2007[28]; however, a study of adults treated in the same Kaiser Permanente system that showed elimination of racial disparities in childhood perforation rates still found persistent racial disparities in use of laparoscopic appendectomy.[29] Few studies have examined the potential for provider-level factors or nuances of the patient-physician dyad in treatment decision making as a driver of racial-ethnic disparities in appendicitis outcomes.

Larger geographic and healthcare system factors are of special interest to our focus on appendiceal perforation rates before and after Hurricane Katrina. Rural–urban differences in perforation rates are well documented (rural 35.8% vs urban 31.5%) from the nationwide inpatient sample across all age groups.[30] Rural-dwelling patients treated at urban hospitals were more likely to present with perforation compared with rural-dwelling patients treated at rural hospitals (OR 1.23). More specifically, residing in a rural area with traffic patterns indicating high rates of commuting to urban areas is associated with both treatment in tertiary care settings and higher perforation rates, suggesting delays in treatment for patients who have this healthcare utilization pattern.[31] A study from Ontario, Canada showing similar rural–urban differences despite universal health insurance coverage determined that related hospitals with higher usage rates of ultrasound appeared to have lower perforation rates.[32] Comparing results between a public hospital and a private university hospital in New York City, the median length of stay was longer in the public hospital despite a similar complication rate (12% vs 11%), and diagnostically there was greater reliance on computed

tomography scans than on ultrasound.[33] These retrospective studies need further confirmation by randomized trials of diagnostic algorithms, including assessments of surgeon-performed ultrasound versus those obtained through traditional ultrasonography.[34]

Hurricane Katrina affected the demographics of patients presenting for surgical care (resulting from population outmigration) and the acuity and complexity of surgical care required, especially for trauma victims.[35] Despite this, after a brief increase in deaths resulting from septicemia and accidents in early 2006, there has been no lasting impact on mortality rates in Orleans Parish.[36,37] Residing in the hurricane-affected counties, however, was associated with a risk change to a proportionately higher posthurricane versus prehurricane appendiceal perforation rate. Because ruptured appendix is caused by delays in care for appendicitis (both in reaching the hospital or ED and in the transition from the ED to the operating room), these findings suggest that residents of high-impact counties had greater difficulty accessing effective care after Hurricane Katrina than before. African Americans experienced greater difficulty accessing care and had significantly higher rates of perforation versus whites both pre- and posthurricane.

Our study had certain limitations. The accuracy of Medicaid data relies on the accurate input of patient demographic information and accurate coding of diagnosis and procedures. In addition to the usual coding limitations of administrative claims data, there is also the possibility that the disaster itself may have disrupted the proper coding and submission of billing claims for hospital-based procedures because of crippled computer systems or inefficient paper-based workflow changes.[38,39]

Both Medicare and Medicaid claims data have been used specifically to monitor surgery rates and complications rates for various surgical procedures, including appendectomy, cholecystectomy, breast cancer surgery,[40,41] and colon polypectomy,[42] establishing a reasonable history of accuracy for claims data. For example, compared with clinical records, claims data in patients undergoing colonoscopy show sensitivity for colon polyps of 93.4%, with a specificity of 97.8%.[43] Our results also may have been affected by a disruption in billing efficiency after the storm because patients may have lost their documentation of eligibility during the storm.[44,45]

Conclusions

Our study demonstrates that health professionals and hospital systems were able to maintain relatively similar levels of effectiveness in preventing appendiceal perforations despite the impact of an enormously destructive hurricane. The baseline level of racial disparities in perforation rates and the worsening of the African American–white gap in perforation rates post-disaster are still troubling, however. Further study is required to confirm these findings and seek solutions for maintaining and improving access during disasters, when healthcare systems are acutely strained.

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Key Points

- Our findings provide new and strong evidence that health professionals and hospital systems were able to maintain effective levels of care before and after Hurricane Katrina.
- Perforation rates in African Americans suggest ongoing racial disparities during disasters.

Table 1

Characteristics (mean, 95% CI) of hurricane high- and low-impact counties in Louisiana and Mississippi, 2005, and characteristics of appendectomy discharges for children (0–18 years), 2004–2007

	High-impact counties	Low-impact counties
	N = 9.0	N = 133.0
% MSA *	100	27 (19–34)
Population density (population/mi^2) *	567.94 (102.1–1238)	74.52 (55.77–93.28) $P < 0.05$
Population ages 0–18 y living below poverty level, %	24.51 (19.58–29.44)	33.12 (31.46–34.79)
African American population, % *	14.06 (6.21–21.92)	22.69 (20.79–24.59)
Hospitals with ED *	1.79 (0.58–2.98)	0.98 (0.82–1.13)
Hospitals with surgical units *	1.44 (0.49–2.39)	0.66 (0.52–0.81)
Surgeons/100,000 population *	11.1 (4.45–17.79)	5.9 (4.77–6.99)
Distribution of claims	N = 532	N = 2700
Age, y	11.88 (11.45–12.31)	11.85 (11.67–12.03)
Race, %		
Black	38.24	38.0
White	47.59	54.38
Other	6.68	3.13
Sex, %		
Male	38.50	38.15
Female	61.50	61.85

* Results significantly different at $\alpha = 0.05$ for t test or χ^2 test.

CI, confidence interval; ED, emergency department; MSA, Metropolitan Statistical Area.

Table 2

Perforation rates by race and ORs from mutually adjusted logistic regression model, pre- and post-Hurricane Katrina in hurricane high- and low-impact counties

		High impact				Low impact			
	Total	Prehurricane		Posthurricane		Prehurricane		Posthurricane	
	N %	N %	OR (95% CI)	N %	OR (95% CI)	N %	OR (95% CI)	N %	OR (95% CI)
Total	1297	90	NA	111	NA	473	NA	619	NA
	40.02	35.71		39.64		41.24		39.83	
Age, y									
≤10	551	34	1.31 (0.74–2.33)	53	1.64 (0.97–2.78)	205	1.48 (1.15–1.89)	255	1.19 (0.96–1.48)
	44.36	40.96		47.32		47.24		41.9	
>10	746	56	1.00	58	1.00	268	1.00	364	1.00
	37.32	33.14		34.52		37.59		38.48	
Race									
African American	582	47	2.16 (1.23–3.80)	51	2.46 (1.41–4.28)	204	1.46 (1.14–1.87)	279	1.71 (1.38–2.12)
	46.8	43.93		49.51		46.36		47.2	
Other	56	6	1.82 (0.60–5.57)	12	1.65 (0.70–3.85)	18	2.43 (1.15–5.18)	20	1.25 (0.69–2.26)
	45.2	40.00		41.38		60		40.8	
White	593	31	1.00	37	1.00	255	1.00	287	1.00
	34.5	26.96		28.91		36.83		34.4	
Sex									
Male	807	52	0.97 (0.56–1.69)	76	1.99 (1.16–3.42)	309	1.31 (1.02–1.68)	367	1.02 (0.82–1.26)
	41.92	35.86		44.97		44.08		40.5	
Female	490	38	1.00	35	1.00	164	1.00	252	1.00
	37.23	35.51		31.53		36.77		38.9	

CI, confidence interval; OR, odds ratio.

Table 3

ORs and CIs for appendix perforation from multilevel logistic models

	Prehurricane	Posthurricane
County level		
High impact vs low impact	0.62 (0.34–1.13)	1.14 (0.56–2.31)
Population density (OR for increase of 100 people/mi^2)	1.02 (0.97–1.08)	0.99 (0.93–1.06)
Population ages 0–18 y living below poverty level, %	1.00 (0.98–1.03)	1.02 (0.99,1.05)
African American population, %	1.01 (0.98–1.03)	1.00 (0.97–1.03)
Hospitals with ED (OR for increase of 1 hospital)	1.17 (0.91–1.51)	1.24 (0.91–1.69)
Hospitals with surgical unit (OR for increase of 1 hospital)	0.96 (0.72–1.28)	0.97 (0.69–1.35)
Surgeons/100,000 population	0.97 (0.95–1.00)	0.97 (0.94–1.00)
Individual discharge level		
Age, ≤10 y vs 11–18 y	1.46 (1.15–1.84)	1.24 (1.00–1.53)
Race		
African American vs white	1.53 (1.18–1.98)	1.82 (1.44–2.30)
Other vs white	2.14 (1.13–4.07)	1.48 (0.88–2.49)
Sex		
Female vs male	0.81 (0.64–1.02)	0.93 (0.75–1.14)

CI, confidence interval; ED, emergency department; OR, odds ratio.