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Rising Closures Of Hospital Trauma Centers Disproportionately Burden Vulnerable Populations

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ABSTRACT Closures of hospital trauma centers have accelerated since 2001. These closures may disproportionately affect disadvantaged communities. We evaluate how driving time between ZIP code areas and the nearest trauma centers—a proxy for access, given the time-sensitive nature of trauma care—changed nationwide during 2001–07. By 2007, sixty-nine million Americans (24 percent of the population) had to travel farther to the nearest trauma center than they did in 2001, and almost sixteen million people had to travel an additional thirty minutes or more. Communities with disproportionately high numbers of African American residents, uninsured people, and people living in poverty, as well as people living in rural areas, were more likely than others to be thus affected. Because mortality from traumatic injuries has also worsened for these vulnerable populations, policy makers should learn more about the possible connections—and consider such measures as paying trauma centers serving these communities higher amounts for treatment of injuries.

Timely access to care is critically important for patients with traumatic injuries or emergent conditions. Although health outcomes depend on many factors, including severity of injury, trauma patients who do not receive care in a timely fashion are at increased risk of death.^{1–3}

Hospital trauma centers are integral to emergency care because they reduce death rates from injuries.⁴ A sizable proportion of the public mistakenly believes that emergency departments are synonymous with trauma centers.⁵ However, hospitals that offer trauma center services must meet a long list of specific criteria to be designated or certified by a government or independent entity to provide trauma care in defined areas. Depending on the level of the trauma center designation, such criteria include specific staffing requirements, such as the presence of trauma surgeons; twenty-four-hour capacity for

imaging; capabilities for burn care, and helicopter landing pads.

The importance of trauma centers is widely recognized. Indeed, objective 8 of the Injury and Violence Prevention topic area of the Department of Health and Human Services' Healthy People 2020 initiative is to increase access to trauma care in the United States.⁶ Unfortunately, trauma centers have been closing at accelerated rates over the past two decades. In 1990 there were 1,125 US trauma centers; by 2005, 339 had closed. This compares with 66 closures between 1981 and 1991.^{7–10} The closures from 1990 on have been attributed to the high costs of trauma care; the fact that trauma centers were treating more patients who were unable to pay; and underfunding, in that Medicare has implemented several payment cuts, and the rapid growth of managed care in the 1990s resulted in lower negotiated payments.^{11–14} Thus, public health experts and patients are concerned that the documented ben-

efits of trauma centers^{13,15,16} might not be equally available to all populations.

Previous research suggests that hospital closures might affect the distance patients must travel to obtain care. Longer travel distances to hospitals can lead to negative patient outcomes, especially for time-sensitive conditions, such as stroke.^{1-3,17} This may hold true for hospital trauma center closures as well, because there is often just one so-called golden hour following a serious injury during which patients can be saved. Few studies have examined geographic access to trauma care for vulnerable populations measured by “time to arrival” or “distance to care” as an outcome variable.

Our study examined whether geographic access to care, defined here as driving time to the nearest trauma center, improved or deteriorated between 2001 and 2007 for vulnerable populations: specifically, the socioeconomically disadvantaged, racial and ethnic minorities, and rural communities. We considered driving time to the nearest trauma center as the key variable because the majority of field trauma cases are transported on roadways, and transfers of patients between hospitals were beyond the scope of the study.

Study Data And Methods

DATA SOURCE To identify existing trauma centers between 2001 and 2007, we extracted data from the American Hospital Association Annual Surveys. We included all general, acute, short-stay hospitals that offered trauma center services. The survey data also included trauma center characteristics such as size, ownership, and teaching status. We did not use the Trauma Information Exchange Program database, which identifies trauma centers based on the American College of Surgeons Committee on Trauma definition, because data were not available for the entire study period.

The American Hospital Association survey asks hospitals to identify themselves as a regional resource trauma center, community trauma center, rural trauma hospital, or other (state-specific). For our analysis, a hospital is considered a trauma care center if it provides any type of trauma care specified in the American Hospital Association surveys (all levels included).

We linked this data set with the 2000 census to obtain the demographic characteristics of US communities as defined by ZIP code tabulation area level. This level was created by the Census Bureau for statistical calculations of Postal Service ZIP codes and in most cases is identical to ZIP codes.

Thus, we were able to calculate community characteristics such as percentage of population under the federal poverty level; number of unemployed residents; and racial and ethnic minority, elderly, and foreign-born populations. We also obtained the longitude and latitude coordinates of each ZIP code’s population center.

We further supplemented our data set with county-level percentages of uninsured residents, which we obtained from the 2005 Area Resource Files maintained by the federal government.¹⁹

DISTANCE TO TRAUMA CARE We obtained the longitude and latitude coordinates of each trauma center’s location using physical address or heliport location in order to calculate the distance residents had to travel to reach their nearest trauma center.¹⁸ Although geographic availability of a trauma center is only one component of health care access, it is important because of trauma’s acute nature. In this study we looked at the geographic availability of trauma centers as a reasonable, but incomplete, proxy for access to trauma care.²

We measured distance between a trauma center’s location and a ZIP code’s population center location by calculating the straight-line distance between the two. The distance calculation based on longitude and latitude coordinates is highly correlated with actual driving distance, especially for urban areas.^{20,21}

To better understand how trauma center closures affected people during the period 2001–07, we converted the distance between a ZIP code’s population center and the nearest trauma center into driving time. We accomplished this by using a previously validated formula to convert straight-line distance into actual transportation time.^{21,22} We then determined how driving time to the closest trauma center changed between 2001 and 2007.

We classified the communities according to whether the calculated driving time between each community and the nearest trauma center did not increase or actually decreased, and, if it increased, by more or less than thirty minutes between 2001 and 2007. Because there is no standard measurement for changes in driving time, we looked at the overall mean for the communities with a positive increase in driving time, which was twenty-nine minutes. We chose a thirty-minute increase as the cutoff point for trauma access change categories because it represents a meaningful increase in driving time while ensuring adequate sample size.

DATA ANALYSIS Our unit of analysis was at the community level, defined by ZIP codes established by the Census Bureau. First, we analyzed the change in driving time to the nearest trauma center from 2001 to 2007. We compared area

characteristics between communities that experienced no increase in driving time and those that experienced increased driving time.

We performed a multinomial regression to determine which factors were associated with the community's risk of experiencing an increase in driving time to the nearest trauma center. The change-in-driving-time outcome variable was categorical and was defined either as no change in driving time; increase in driving time of fewer than thirty minutes; and increase in driving time of thirty minutes or more.

The multinomial logit is the appropriate estimation method because our dependent variable is categorical and not continuous. We describe the predicted variables in more detail below.

All regression models were weighted by the population of each community in order to obtain population-based estimates of the relative risks. The communities included in the study are nationally representative of more than 99 percent of the US population, according to the 2000 census. All analyses were done using the statistical analysis software Stata, version 11.

PREDICTOR VARIABLES Our main objective was to examine whether vulnerable populations experienced a disproportionate increase in driving times to trauma centers. We divided the communities into urban and rural categories based on whether the ZIP code was in a Metropolitan Statistical Area as defined by the 2000 census. After differentiating rural and urban areas, we categorized each area according to whether the community had low, medium, or high shares of vulnerable characteristics.

We classified each community using the following steps. First, to characterize vulnerability, we looked at the percentage of economically disadvantaged, racial and ethnic minority, uninsured, foreign-born, and elderly populations, as detailed below.¹⁹ Second, we categorized each community's level of vulnerable population into low, medium, and high by tertiles of the distribution for each of these vulnerability characteristics in rural and urban areas across the United States.

For instance, an urban ZIP code was classified as having a "high" share of elderly residents if the percentage of its elderly population was in the upper third (67–100 percent) of the distribution of elderly residents in all urban areas. By including the urban/rural indicator and the three-level categorization of vulnerable population, we determined whether rural communities experienced access deterioration relative to urban communities, and if so, how vulnerable populations fared within them.

We categorized vulnerable populations in each ZIP code as follows.

► **ECONOMICALLY DISADVANTAGED:** We included two measures of economic disadvantage. We divided communities into three categories based on distribution of the percentage of population below the federal poverty level for urban and rural areas separately, and similarly for the unemployed. Both measures highlight weak economies that may be vulnerable to changes in health care access.^{23,24}

► **RACE AND ETHNICITY:** We considered racial and ethnic minorities using standard census measures: non-Hispanic African American; Hispanic; and other populations that were not Hispanic or African American. These were compared with the reference group of non-Hispanic whites.

► **FOREIGN-BORN:** Foreign-born populations have more documented barriers to health care than do US-born populations.²⁵ We included this characteristic because specific geographic disparities in access to care for foreign-born populations have not been studied.

► **UNINSURED:** We categorized communities into low, medium, and high shares of uninsured residents based on the percentage uninsured for the community. Note that percentage uninsured is not available at the ZIP code level because the 2000 census did not collect health insurance information. The smallest geographic unit with a reliable uninsured percentage was the county level; therefore, ZIP codes that belong to the same county would share the same percentage of uninsured residents.

► **ELDERLY:** Elderly patients face higher risks of mortality during trauma, which makes access to trauma care important for this population.²⁶ We identified elderly populations according to the census definition as people age sixty-five or older.

OTHER COVARIATES In addition to population composition, we controlled the supply of hospital care by comparing changes in geographic access to trauma care while holding baseline access constant. We defined the *hospital market* as a fifteen-mile radius from the population center of the ZIP code. This fixed-radius market definition is a standard measure of hospital markets.^{27–30}

We included in the baseline the following indicators for the type of hospital care available within each community's hospital market: the presence of at least one trauma center (for some rural communities, there is no trauma center within the fifteen-mile radius) and the presence of for-profit, government, and teaching hospitals.

LIMITATIONS We recognize several limitations to our study. First, although the definitions of *trauma centers* have changed over time, those provided by the American College of Surgeons

Committee on Trauma are considered the standard. However, there is no database of trauma centers verified by this group that reaches back to 2001. Thus, identification of trauma centers is based on self-report according to the definition in the American Hospital Association Annual Survey.

Despite the slightly different definitions used by the two bodies, we were able to calibrate our data for one year between the hospital survey and the Trauma Information Exchange Program, which is based on the American College of Surgeons' definitions. We found little difference between the numbers of levels I–III trauma centers in our analysis.

Using American Hospital Association data may have affected the rural data because self-report might not be as accurate as certified data from the Trauma Information Exchange Program, especially for levels III and IV trauma centers, which exist in greater numbers in rural areas.¹³

The second limitation is that ZIP code-level census data are available only every ten years. Although community characteristics may change within a decade, they should not affect our qualitative results, because these characteristics are highly correlated over the years.

Third, although distances were correlated to travel time, two people from the same ZIP code might experience different driving time to the same trauma centers, especially in rural communities. For example, some rural communities may have established relationships with air transport services to urban trauma centers; therefore, distance to the nearest trauma center might not be the most relevant proxy for access if patients receive timely airlift. We do know that air transport accounts for only 3 percent of all trauma transports and therefore should not invalidate our results.³¹

Additionally, we did not account for Emergency Medical Service response and dispatch time, because we assumed that such time was constant throughout the study period.

Study Results

BASELINE DISTANCE TO TRAUMA CENTERS IN 2001 Our final sample consisted of 31,475 ZIP codes covering 283 million people (about 99 percent of the US population). To illustrate the baseline distribution, Exhibit 1 shows the 2001 distance to the nearest trauma center in three discrete categories of geographic availability: those with trauma centers within ten miles; between ten and thirty miles; and more than thirty miles.

Overall, nearly three-quarters of the US pop-

ulation resides within ten miles of a trauma center. At the other extreme, 14 percent of the population lives more than thirty miles from a trauma center. The distribution is quite different between urban and rural communities: 71 percent of those in urban areas are within ten miles of the nearest trauma center, and 9 percent are more than thirty miles away. In rural areas, only 24 percent of the population have trauma centers within ten miles, while 29 percent do not have trauma centers within that distance.

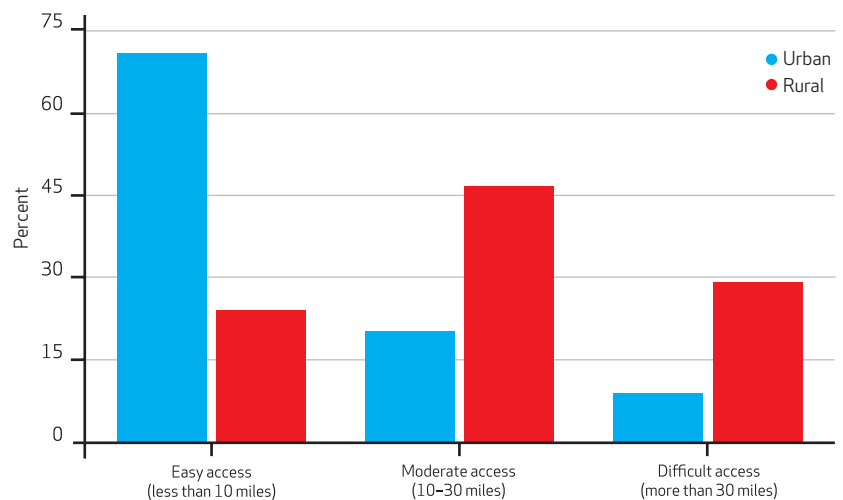
CHANGES IN DRIVING TIME FROM 2001 TO 2007 Appendix Exhibit 1 displays the location of trauma center closures across the United States between 2001 and 2007.³² Most closures occurred in urban areas because more trauma centers are located in these areas. Yet rural areas have also been affected by closures.

Exhibit 2 displays the means of the variables used in the statistical model, categorized by the three access-change categories. Approximately 76 percent of ZIP codes (214 million US residents) experienced no increase in driving time to the nearest trauma center.

POPULATIONS AT RISK FOR INCREASED DRIVING TIME We present the multivariate results in Exhibit 3. The overall model is statistically significant ($p < 0.01$). We present the results pertaining to the comparison between the communities that experienced at least a thirty-minute increase in driving time and communities that experienced no increase, because this comparison has the greatest policy implications. Additional results are presented in Appendix Exhibit 2.³²

EXHIBIT 1

Population Access To Trauma Care Services In Urban And Rural Areas, 2001



SOURCE Authors' analysis of data from the American Hospital Association Annual Survey, 2001, and census 2000 summary file 3 technical documentation, 2002.

EXHIBIT 2

Population And Health Care Market Characteristics, By Trauma Services Access Change Categories, 2001-07

Characteristic	Whole sample	Increase in driving time, 2001-07		
		None	<30 min	≥30 min
BASELINE VULNERABLE POPULATION CHARACTERISTICS BY ZIP CODE				
Share of population below federal poverty level				
Low share (ref) ^a	33%	33%	37%	25%
Medium share	33	33	33	39
High share	33	34	30	36
Share of unemployed population				
Low share (ref)	33%	33%	36%	30%
Medium share	33	33	35	38
High share	33	34	29	32
Share of African American population				
Low share (ref)	33%	34%	29%	32%
Medium share	33	33	35	30
High share	33	32	37	38
Share of Hispanic population				
Low share (ref)	34%	33%	33%	39%
Medium share	33	33	35	34
High share	33	34	32	26
Share of other nonwhite population				
Low share (ref)	34%	32%	35%	44%
Medium share	33	34	33	31
High share	33	34	31	25
Share of uninsured population				
Low share (ref)	35%	36%	33%	26%
Medium share	35	34	38	44
High share	30	30	29	30
Share of elderly population				
Low share (ref)	33%	33%	36%	32%
Medium share	33	34	31	33
High share	33	33	33	34
Share of foreign-born population				
Low share (ref)	33%	33%	33%	43%
Medium share	33	32	37	36
High share	33	35	31	20
Urban/rural status				
Urban (ref)	81%	82%	86%	57%
Rural	19	18	14	43
Average population size	28,273	28,404	29,719	21,646
BASELINE HOSPITAL MARKET CHARACTERISTICS WITHIN 15-MILE RADIUS				
Presence of at least 1 trauma center	71%	71%	75%	60%
Presence of for-profit hospitals in the market	52	52	55	37
Presence of government hospitals in the market	47	48	49	31
Presence of teaching hospitals in the market	47	49	53	6
No. of observations	31,475	23,914	5,038	2,523
Population size	282,779,035	213,860,611	53,090,278	15,828,146

SOURCE Authors' analysis of data from the American Hospital Association Annual Survey, 2001-07, and census 2000 summary file 3 technical documentation, 2002. **NOTES** Thresholds for urban communities are 6 percent and 13 percent for poverty; 2 percent and 3 percent for unemployment; 2 percent and 9 percent for African American; 3 percent and 12 percent for Hispanic; 5 percent and 14 percent for other nonwhite; 5 percent and 7 percent for elderly; 4 percent and 13 percent for foreign-born; and 12 percent and 16 percent for uninsured. Thresholds for rural communities are 10 percent and 16 percent for poverty; 2 percent and 3 percent for unemployment; 0.3 percent and 4 percent for African American; 1 percent and 3 percent for Hispanic; 2 percent and 5 percent for other nonwhite; 7 percent and 9 percent for elderly; 1 percent and 3 percent for foreign-born; and 12 percent and 16 percent for uninsured. ^aZIP codes that belong to the same county share the same percentage uninsured.

Communities with a higher share of residents under the federal poverty level were at higher risk of facing at least a thirty-minute increase in driving time in both urban and rural areas (Exhibit 3). High-poverty communities were

1.32 times more likely to face an increase in driving time of thirty minutes or more compared with low-poverty communities.

In addition, communities with high shares of African American residents are also at a higher

EXHIBIT 3
Likelihood That Driving Time To The Nearest Trauma Center Increased By At Least Thirty Minutes Between 2001 And 2007

Characteristic	Percent with ≥30-minute increase	Relative risk ratio	95% confidence interval
BASELINE VULNERABLE POPULATION CHARACTERISTICS BY ZIP CODE			
Share of population below federal poverty level			
Low share (ref)	7%	1.00	
Medium share	8	1.24**	1.00, 1.54
High share	10	1.32**	1.03, 1.70
Share of unemployed population			
Low share (ref)	7%	1.00	
Medium share	8	1.07	0.88, 1.30
High share	9	0.98	0.79, 1.22
Share of African American population			
Low share (ref)	8%	1.00	
Medium share	7	1.08	0.88, 1.33
High share	8	1.28**	1.04, 1.59
Share of Hispanic population			
Low share (ref)	9%	1.00	
Medium share	8	0.94	0.76, 1.17
High share	7	1.04	0.76, 1.44
Share of other nonwhite population			
Low share (ref)	8%	1.00	
Medium share	8	0.71***	0.57, 0.89
High share	9	0.70**	0.51, 0.94
Share of uninsured population ^a			
Low share (ref)	6%	1.00	
Medium share	9	1.69***	1.37, 2.08
High share	10	1.55***	1.21, 1.98
Share of elderly population			
Low share (ref)	8%	1.00	
Medium share	7	0.90	0.74, 1.11
High share	8	0.98	0.81, 1.19
Share of foreign-born population			
Low share (ref)	9%	1.00	
Medium share	8	0.98	0.79, 1.22
High share	6	0.55***	0.39, 0.76
Urban/rural status			
Urban (ref)	5%	1.00	
Rural	11	2.52***	2.06, 3.08
Log (ZIP code-level population)	—	1.14***	1.05, 1.24
BASELINE HOSPITAL MARKET CHARACTERISTICS WITHIN 15-MILE RADIUS			
Presence of at least 1 trauma center	—	1.65***	1.38, 1.97
Presence of for-profit hospitals	—	1.06	0.88, 1.29
Presence of government hospitals	—	0.89	0.75, 1.07
Presence of teaching hospitals	—	0.08***	0.05, 0.11

SOURCE Authors' analysis of data from the American Hospital Association Annual Survey, 2001–07, and census 2000 summary file 3 technical documentation, 2002. **NOTES** N = 31,475. Multinomial logit regression results. Reference group is no increase in driving time. ^aZIP codes that belong to the same county share the same percentage uninsured. **p < 0.05 ***p < 0.01

relative risk of experiencing an increase of thirty minutes or more in driving time to the nearest trauma center compared with areas with low proportions of African American residents. Communities with medium or high shares of uninsured residents are 1.69 and 1.55 times, respectively, more likely to experience increases in driving time of thirty minutes or more, when compared with communities with low shares of uninsured residents.

We did not find other vulnerable populations to be at higher risk of increased driving time. Indeed, for areas with high proportions of foreign-born residents, the relative risk of a greater drive time actually decreased (Exhibit 3).

We also found that rural communities, known to have higher baseline driving times to the nearest trauma center, have an even higher risk of experiencing a significant increase in driving time compared with urban areas.

Discussion

By 2007, sixty-nine million Americans (24 percent of the population) had to travel farther to the nearest trauma center than they did in 2001, and almost sixteen million people had to travel an additional thirty minutes or more. This deterioration in geographical access to trauma centers has been more acute in communities with high shares of poor, uninsured, and African American populations.

Our findings reveal that rural communities have a higher risk of experiencing declines in geographic access than urban communities. This is troubling because, at baseline, residents in these areas already must travel farther to reach their nearest trauma center. As our results and prior studies demonstrate, rural communities suffer from a lack of generalist and specialist physician presence.³³ These findings add to mounting evidence of a worsening of access to emergency care in rural areas. In fact, between 1990 and 1999, 11.3 percent of rural hospitals closed, while emergency visits to such hospitals rose more than 20 percent.³⁴

Despite an overall emphasis on reducing disparities in the US health care system, our findings make it clear that geographic access to trauma centers, measured by driving times, has not improved. Indeed, it has deteriorated for vulnerable populations.

REASONS FOR DECLINE There may be several factors at play in the decline we observed. Trauma centers provide expensive care to higher proportions of vulnerable populations and are less able to recover their costs compared to hospitals without trauma centers.^{8,35,36} Because urban and suburban trauma centers are usually considered unprofitable, they often depend on public financing mechanisms to survive. And because there are no federal or state requirements dictating the number and level of trauma centers for any given community, the decision to close a trauma center is mostly driven by market factors and the hospital's mission.

In times of economic hardship, some trauma center closures might be due to coordination and consolidation of health care centers to improve efficiency and outcomes. We therefore cannot assume that closures uniformly harm the community. Optimizing patient outcomes may therefore require better coordination of trauma services at the regional level.³⁷ The purpose of this analysis was to document how geographic access to trauma centers changed over time, with the understanding that financial pressures and other market factors predict trauma center survival.¹⁰

Trauma center closures are less often predicated on purposeful evaluation of health outcomes and desire to shut down poorly performing facilities, and more often the result of financial hardship of facilities and their inability to offer a wide selection of services,^{7,38} especially in communities that need them most. It is important to note that a decreased number of trauma centers does not necessarily imply poorer care for these populations. Such a determination of quality depends on the system's ability to triage and transport (including by air) patients to the most appropriate facilities.

IMPACT ON VULNERABLE POPULATIONS Our findings provide evidence that poor and African American communities and rural residents are disproportionately affected by deteriorating trauma care access. Over the past two decades, disparities in health indicators such as mortality from traumatic injuries have worsened for vulnerable populations including African American, Hispanic, and low-income groups.³⁹ Deteriorating access to emergency care, such as that available in trauma centers, could create systemic disparities of care for vulnerable patients.^{40,41}

POLICY IMPLICATIONS We do not attempt to draw causal relationships; rather, we wish to substantiate concerns about increased trauma center closures in vulnerable communities and to alert policy makers about them. Potential policy implications could include bolstering financing to support trauma care, such as higher reimbursement for treatment of injuries, and doing so especially for hospitals that see a larger proportion of African American, uninsured, or poor populations. For rural areas, it is critical that agreements between existing trauma centers be created to potentially increase access to air transport.

CONCLUSION It is important to build upon this research to study how trauma center closures affect patient outcomes. The overall goal is to progress toward a health care system that provides acute care that is equitable, competent, and cost-effective. Achieving this goal does not equate to establishing a trauma center in every community. However, it does require careful examination of the effects of closures on individual communities—not simply as dictated by market forces or pressures.

The goal of our research is to provide an empirical basis for policy makers and health care providers to establish appropriate regional strategies to provide efficient and equitable access to life-saving care. ■

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Renee Yuen-Jan Hsia is an attending physician in the emergency department at San Francisco General Hospital.

In this month's *Health Affairs*, Renee Yuen-Jan Hsia and Yu-Chu Shen show that closures of hospital trauma centers, which have accelerated in recent years, may disproportionately affect disadvantaged communities.

The authors examined changes in driving time to trauma centers—a proxy for access, given the time-sensitive nature of treatment for injuries. They found that by 2007, sixty-nine million Americans, or almost one in four, had to travel farther to the nearest trauma center than they did in 2001, and that vulnerable populations were most affected. They argue that policy makers should learn more about the health impact on these populations and should consider such measures as paying trauma

centers serving these communities higher amounts for treatment of injuries.

Hsia is an attending physician in the emergency department at San Francisco General Hospital and an assistant professor of emergency medicine at the University of California, San Francisco (UCSF). At UCSF, she has been principal investigator on a number of intramural and extramural projects, including the National Institutes of Health Clinical Research Career Development Award and the Robert Wood Johnson Foundation Physician Faculty Scholars award.

Hsia received her medical degree from Harvard Medical School and her master's training in health policy, planning, and financing at the London School of Economics and the London School of Hygiene and Tropical Medicine.



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Shen, who frequently collaborates with Hsia on research, is an associate professor of economics in the Graduate School of Business and Public Policy, Naval Postgraduate School, in Monterey, California. Her expertise is in three broad areas: how organizational changes and financial incentives in health care markets affect providers' behavior and patient care; public health capacity and access to care for vulnerable populations; and issues related to disparities in health care and health insurance, such as documenting disparities in access to emergency medical services and analyzing whether such disparities affect the quality of care. Shen earned her doctorate in health policy at Harvard.