RESEARCH

Regional Health System Response to the 2007 Greensburg, Kansas, EF5 Tornado

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ABSTRACT

Background: On May 4, 2007 an EF5 tornado hit the rural community of Greensburg, KS, destroying 95% of the town and resulting in 12 fatalities.

Methods: Data was requested from the emergency medical services units that initially responded and the regional hospitals that received people injured in the tornado within 24 hours following the tornado. Requested data included patient age and sex, and injury severity score or *ICD-9* codes. Critical mortality, or the number of deaths of critically injured patients, was also calculated.

Results: The extensive damage caused by the tornado effectively destroyed the infrastructure of the community and created enormous challenges for emergency medical services responders, who were unable to record any triage data. Area hospitals treated 90 patients, who had an average injury severity score of 6.4. Age was found to be related to injury severity, but no relationship between sex and injury severity was found. Critical mortality was found to be 18% for this event.

Conclusions: Injury severity score has seldom been used to analyze natural disasters, especially tornadoes, although such analysis is helpful for understanding the magnitude of the disaster, comparing to other disasters, and preparing for future incidents. Advanced warning and personal preparedness are important factors in reducing tornado-related injuries and deaths. (*Disaster Med Public Health Preparedness.* 2007;1:90–95)

Key Words: tornado, injury severity score, critical mortality, age

At 9:45 PM on May 4, 2007, Greensburg, KS, a rural community of approximately 1500 residents, was struck by an Enhanced Fujita Scale (EF) 5 tornado.[1] This event marked the first time since the Enhanced Scale went into effect February 1, 2007 that the EF5 measurement was used, and was the first confirmed 5-scale tornado since the one that struck Oklahoma City and its suburbs in 1999.[1,2] The Greensburg tornado was approximately 1.7-mi wide and traveled 22 mi with sustained wind speeds of 205 mph.[3] The Greensburg tornado is unique in the overwhelming percentage of the community destroyed: an estimated 95% of the homes and businesses in Greensburg were destroyed, and the other 5% were severely damaged.[4] Kansas Emergency Management assessments placed the number of homes destroyed in the Greensburg area at 961, with an additional 105 homes sustaining major damage and an additional 67 sustaining minor damage.[5] In addition to the residences destroyed, 110 of Greensburg's businesses sustained major damage and 24 sustained minor damage.[5]

The destruction of the community's entire infrastructure presented a distinctive challenge for emergency response because responders were also victims themselves, and typical places of response, such as the local hospital and health department, were destroyed. This article is a retrospective analysis of the regional health system response to these events, and the response was developed through a collaborative effort of regional hospitals and emergency medical services, local and state public health entities, and the regional hospital coordination entity.

TORNADO EPIDEMIOLOGY

Tornadoes are severe wind storms that are characterized by violent rotating winds that converge into a funnel-shaped vortex. Since the mid-1970s, tornadoes have been classified using the Fujita (F) Scale, which correlates wind speeds with damage.[6] In February 2007 this scale was updated to the Enhanced Fujita (EF) scale: EF0 is the weakest, with 3-second wind gust speed of <85 mph, and EF5 is the strongest, with 3-second wind gust speeds of >200 mph.[7] During an average year, around 1000 tornadoes affect the United States, but only 2% of all of these tornadoes are categorized as violent (EF3 and above). Of the violent tornadoes, only around 0.4% achieve EF5 status. Historically, tornadoes in the United States have caused an average of 87 deaths and around 1500 injuries per year.[8]

GREENSBURG DEMOGRAPHICS

Before the May 4, 2007 tornado, Greensburg was a community of approximately 1500 people.[9] As with many rural communities in Kansas, the residents of Greensburg are substantially older than the US average. In 2000 the median age of Greensburg's residents was 46 years, which is 11 years older than the median age of US residents.[9] Additional demographic information is detailed in Table 1.

TABLE 1

Selected Demographic Characteristics of Greensburg, KS*

	No.	%
Sex		
Male	750	48
Female	824	52
Total	1574	100
Race		
White	1527	97
African American	0	0
American Indian	13	1
Asian American	1	0
Other	16	1
Multiethnic	17	1
Total	1574	100
Ethnicity		
Non-Hispanic	1549	98
Hispanic	25	2
Total	1574	100
Age, y (median, 45.6)		
≤18	338	21
19–34	235	15
35–44	190	12
45–59	325	21
60–74	264	17
≥75	222	14
Total	1574	100
Language spoken in the home		
English only	1408	95
English spoken less than "very well"	21	1
Language other than English	75	5
Total	1483	101
Household income (median, $39,188)		
<$15,000	51	11
$15,000–$34,999	148	33
$35,000–$49,999	89	20
$50,000–$99,999	142	31
$100,000–$149,999	18	4
≥$150,000	7	2
Total	455	101
Housing units (total)	887	
Occupied	730	82
Owner	515	71
Renter	215	29
Vacant	157	18

*Data adapted from US Census Bureau, Census 2000 Demographic Profile Highlights, Greensburg, KS. *http://factfinder.census.gov/home/saff/main.html?_lang=en* (accessed June 22, 2007).

HEALTH SYSTEMS DEMOGRAPHICS

Area hospitals include Kiowa County Memorial Hospital (KCMH), located in Greensburg; Edwards County Hospital in Kinsley, about 24 mi north of Greensburg; Comanche County Hospital in Coldwater, about 24 mi south; Pratt Regional Medical Center in Pratt, about 38 mi east; Western Plains Medical Center in Dodge City, about 45 mi west. Wesley Medical Center and Via Christi Regional Medical Center in Wichita are level I trauma centers and are located about 100 miles east of Greensburg. KCMH, which had 25 beds before the storm, was destroyed by the May 4 tornado.

Before the Greensburg tornado, EMS first responders established a major emergency response group (MERGe), which comprises ambulance services within Kansas EMS Region III with the purpose of interdependent assistance during a disaster. Region III is composed of 19 counties and includes more than 40 ambulance services. MERGe responders from the region collaborated frequently through many previous training and exercise experiences.

METHODS

Because of the extensive damage done to Greensburg's local resources, area hospitals, public health, and EMS, regional collaborations were used to measure the response following the tornado. Data records from all regional responding emergency medical services, hospitals, and coordinating services, were requested, reviewed, and analyzed. Data were requested for patients who were treated within the first 24 hours after the Greensburg tornado, and included basic demographic information (eg, age, sex), types of injuries sustained, and injuries by *International Classification of Diseases-9 (ICD-9)* codes or injury severity scores (ISS).[10] For hospitals that presented only *ICD-9* codes, an ISS was calculated by a member of the research team. Critical mortality, defined as the number of deaths in critically injured patients (ISS scores of ≥15), was also calculated. Approval for this study was obtained by the Human Subjects Committee at the University of Kansas School of Medicine-Wichita and all participating hospitals.

RESULTS

EMS

Although approximately 20 ambulances made themselves available in the first 24 hours after the tornado, only 10 to 15 were active. Of the active ambulances, approximately two thirds were members of MERGe, and the other third were located outside EMS Region III. Geographically, Greensburg is near another EMS region whose counties are not members of MERGe. Upon the arrival of the MERGe team, all of the EMS personnel used simple triage rapid treatment (START) as triage methodology,[11] but due to the overwhelming devastation, it was impossible to record triage data.

Regional Health System In-hospital Casualty Load

As a result of this tornado, 12 fatalities were reported, 10 of which were immediate and 2 were in-hospital deaths. Ninety

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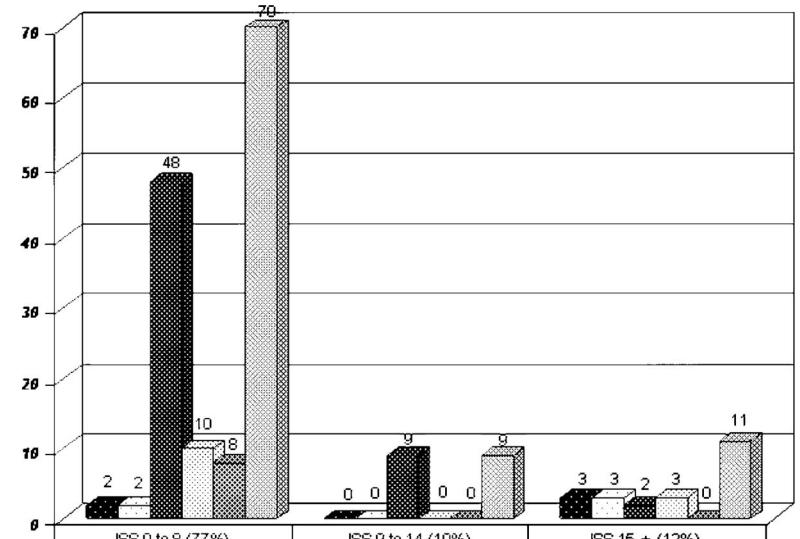
FIGURE 1

Number of patients by ISS and hospital



	ISS 0 to 8 (77%)	ISS 9 to 14 (10%)	ISS 15 + (12%)
Wesley	2	0	3
Via Christi	2	0	3
Pratt	48	9	2
Western Plains	10	0	3
Kinsley	8	0	0
Total	70	9	11

people with tornado-related injuries were treated at area hospitals within the first 24 hours following the tornado (Fig. 1). Because KCMH, Greensburg's local hospital, had been destroyed, individuals with tornado-related injuries were not able to receive care within the city and were sent to hospitals in other Kansas communities, including Pratt, Dodge City, Kinsley, and Wichita. Patients who had been at KCMH before the tornado were transferred to Comanche County Hospital, which received a total of 6 swing bed patients from KCMH. These 6 patients did not have tornado-related injuries and received care only for their pretornado conditions.

> The use of ISS to analyze tornado-related injuries and deaths is relatively new, and few studies have examined tornado-related injuries and deaths using a validated instrument such as the ISS.

Pratt Regional Medical Center (PRMC) was the most likely receiver of patients for 2 primary reasons: first, PRMC is only 30 mi east of Greensburg, whereas Dodge City is 45 mi west, and Wichita is just over 100 mi east; second, the tornado caused destruction west of Greensburg that served as a physical barrier to highway travel to Dodge City, and PRMC was more accessible. Fifty-nine patients were treated at PRMC, with ISS ranging from 0 to 25, with an average ISS of 5.0. PRMC treated 4 patients younger than 18 years and 25 patients ≥60 years old.

Thirteen patients were treated at Western Plains Medical Complex (WPMC) in Dodge City, KS. ISS for these patients ranged from 1 to 20, with an average ISS of 5.9. Only 1 patient was younger than 18 years old and 4 were ≥60 years old.

Wesley Medical Center and Via Christi Regional Medical Center each received 5 patients with tornado-related injuries. Because of the hospitals' Level I trauma status and distance from Greensburg, the majority of patients treated at Wesley and Via Christi had higher ISS. Wesley's patients' ISS ranged from 2 to 38, with an average of 18.4, and Via Christi's ranged from 4 to 36, with an average of 19.6. Neither Wesley nor Via Christi had any patients younger than 18 years, but both hospitals had 2 patients ≥60 years old.

Edwards County Hospital in Kinsley treated 8 patients. Their ISS ranged from 0 to 4, with an average ISS of 1. One patient was under the age of 18, and 3 patients were ≥60 years old.

Among those injured, age and ISS were significantly correlated ($r(81) = 0.182$, $P = .051$), indicating that greater age was positively associated with greater ISS. Furthermore, of the 90 injured people who sought medical care within the first 24 hours, only 6 were children younger than 18 years, and 35 were ≥60 years old.

No significant relationship was found between sex and ISS, although there were more males with higher ISS than females. Numbers of injured people by sex was almost evenly divided between males (n = 46) and females (n = 44).

Overall, the mortality rate of people who presented to the hospital within the first 24 hours was 2%. A critical mortality rate, or how many critically injured patients died in the hospital, can be calculated by identifying the number of hospital deaths and dividing that by the total number of critically injured patients (ISS ≥15). For all of the receiving hospitals within the first 24 hours, the critical mortality rate for the Greensburg tornado was 18%, or approximately 1 out of 6 critically injured patients.

DISCUSSION

The use of ISS to analyze tornado-related injuries and deaths is relatively new, and few studies have examined tornato-related injuries and deaths using a validated insturment such as the ISS.[12–14] Furthermore, a comparison of ISS results from victims of 2 comparable tornadoes has never been done.[14]

On April 8, 1998, an F5 tornado touched down in 2 Alabama counties, resulting in 32 deaths and 224 injuries that were treated at area hospitals. May et al analyzed tornado-related injuries and fatalities using ISS.[14] The average ISS for all of the Alabama tornado–related patients was 6.9, a slightly higher average ISS than the 6.4 for the 90 Greensburg patients who were treated within 24 hours. Our results present ISS only for patients who were treated within the first 24 hours; if all tornado-related patients were included, the average ISS likely would have been even lower because the injuries presented by patients treated later were not urgent and were typically nontrauma. In addition, other Greensburg-area hospitals received residents of nursing facilities and people with tornado-related mental health issues; these patients would not have an ISS and were not included in our results.

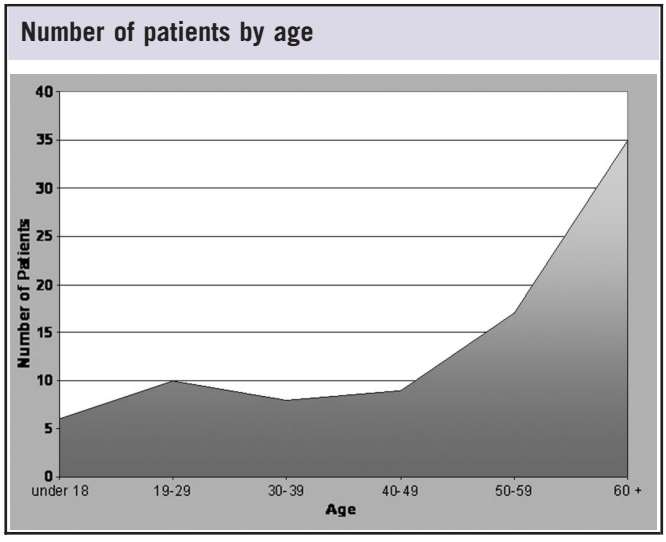
Several factors contributed to the low number of deaths and low average ISS in Greensburg as compared with the April 8, 1998 Alabama tornado. One factor is residents' previous experience with tornadoes. From 2000 to 2005, Kansas experienced an average of 101 tornadoes per year, whereas Alabama experienced a yearly average of 52.6.[8] Although these data do not account for tornado severity or impact on populated areas, they do demonstrate that Kansans may be more likely to have personal experience with tornado conditions, warnings, and drills. Personal experience with tornadoes has been shown to result in survivors' taking increased preparatory and protective actions when faced with subsequent tornadoes.[15]

Tornado warning lead time is another factor that may have affected the number of deaths and injuries in the Greensburg tornado. The average tornado warning lead time has significantly improved recently: in 2004 the average lead time was approximately 13 minutes, a significant improvement from the 1986 average of 5 minutes.[16] The 1998 Alabama tornado touched down at 7:50 PM, and people living in the area that was hit first received a tornado warning 8 to 15 minutes earlier.[17] Areas affected farther on in the path of the tornado received significantly more lead time[18]; the overall average was 13 minutes.

Early warning time and clear warning messages are undoubtedly critical to saving lives.

The 13-minute warning lead time for the Alabama tornado is consistent with the national average and is usually considered good forecasting. Greensburg residents had even more time to prepare, which may have served as a factor contributing to the lower number of injuries and deaths. The first tornado warning was issued for Kiowa County 39 minutes before the tornado struck Greensburg, and tornado warning sirens were activated 20 to 25 minutes before the tornado hit.[19,20] Forecasters then updated the tornado warning to a tornado emergency 12 minutes before the tornado reached Greensburg.[20] The term *tornado emergency* is used infrequently and indicates that an intense tornado is headed directly for a populated region. The use of this heightened warning terminology, in addition to significant warning lead time, likely contrib-

FIGURE 2



uted to the lower numbers of injuries and deaths. Early warning time and clear warning messages are undoubtedly critical to saving lives.

A total of 21% of the Greensburg population was younger than 18 years old, but few children were injured and no children were killed by the tornado. Four children were seen at PRMC, 1 child went to Western Plains Medical Complex, and 1 child went to Edwards County Hospital within 24 hours after the tornado. The average ISS of these injuries was relatively low (3.6), suggesting that children were well protected during the tornado. Conversely, 7 of the 12 tornado-related fatalities were people older than age 60, 35 of the 90 who were injured were older than age 60, and the average age of injured people was approximately 53 years (Table 2, Fig. 2).

A higher age for fatalities and injuries is to be expected in a community like Greensburg that had an above-average percentage of older residents. These trends are important for tornado preparedness because advanced age has often been found to increase risk for tornado-related injuries or death.[21–24] Older adults would benefit from having appropriate tornado safety information taught or reinforced to them, and they need to develop plans for how they will respond to a tornado. Furthermore, family members, friends, or neighbors need to take responsibility for older adults in the community and help them to stay safe during severe weather events. Older adults may have difficulties receiving warning messages or escaping to safe locations quickly, and others in the community can offer valuable assistance.

A variable contributing to the effective response and perhaps the low critical mortality rate was the collaborative response provided by MERGe. When EMS Region III endorsed the use of START, the MERGe team trained to that standard. MERGe members consistently trained and practiced with one another, instituting relationships and a knowledge of one another's abilities, which is vital to functioning during a crisis.

When compared to other mass casualty incidents such as terrorist bombings, a critical mortality rate of 18% is within the normal range. Frykberg has analyzed the critical mortality rates of 10 terrorist bombing incidents, which have an average critical mortality rate of 12.6% and a range of 0% to 37%.[25] The Greensburg tornado is also similar to these disasters in that the majority of injuries experienced were not critical. Frykberg commented that in mass casualty incidents overtriage can be as medically threatening to critically injured survivors as undertriage because a large number of less critically injured patients divert needed resources from people who are critically injured.[25] In rural or isolated locations where local medical care is no longer available, overtriage is difficult to avoid because all of the injured survivors must be sent elsewhere for care.[25] This factor may have contributed to the critical mortality rate in Greensburg because the entire community was destroyed and no local care was available. Unlike the 1998 Alabama tornado, which occurred on the edges of urban Birmingham, the response in Greensburg was hindered by the fact that the entire community was destroyed and all of the patients had to be transported a long distance before any substantial medical care could be provided.

In rural or isolated locations where local medical care is no longer available, overtriage is difficult to avoid.

One of the limitations of the response was that emergency medical services triage data for Greensburg were not recorded; therefore, overtriage and undertriage rates could not be analyzed. This, however, is a reflection of the chaos that tends to accompany disasters, especially when buildings, roadways, tables, chairs, power, and communications have effectively disappeared. Also, there may have been other hospitals outside this area that received tornado-related injuries that were not included in this study. Even if this were the case, these patients would probably have needed less urgent care and would likely have had a low ISS, therefore not significantly contributing to the average ISS or critical mortality rate.

TABLE 2

Demographics of Tornado-related Deaths

Age	Sex
46	Male
48	Male
51	Male
57	Male
62	Male
77	Male
79	Male
84	Male
52	Female
71	Female
75	Female
77	Female

CONCLUSIONS

The regional health system worked collaboratively to effectively mitigate excess mortality and morbidity after the Greensburg tornado as compared with previous F5 and EF5 tornadoes. The Greensburg tornado is unique in the overwhelming percentage of the community destroyed: the community was essentially destroyed, from infrastructure and buildings to communication systems. This incredible devastation challenged regional health systems at an unprecedented level and in ways that disaster preparedness planners

do not often train for or practice. The critical mortality rate for this tornado demonstrates the severity of the disaster and the challenge of triaging injured patients in a completely destroyed rural community.

Despite the incredible devastation and overwhelming circumstances, many things worked in Greensburg's favor, including its excellent warning system, the abundant lead time, its well-prepared residents, its well-trained and collaborative EMS personnel, and its capable regional hospital system. These factors are likely to have helped reduce the overall ISS and contributed to the low number of related fatalities. Furthermore, what happened in Greensburg demonstrates that tornado preparedness is vitally important for communities in tornado-prone areas, and older adults in particular would benefit from having a tornado preparedness plan and establishing relationships with others who can assist them during dangerous storms. Citizens benefit by preparing for tornadoes in advance, and perhaps more important, by promptly heeding warnings when they are provided.

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