Fatal Traumatic Brain Injury, West Virginia, 1989–1998

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SYNOPSIS

Objective. The objective of this study was to describe fatal cases of traumatic brain injury (TBI) among West Virginia residents.

Methods. The authors analyzed data from the National Center for Health Statistics Multiple Cause of Death tapes for the period 1989–1998. They compared West Virginia's annualized average TBI death rate with the rates of other states and with the rate among U.S. residents for the same period. U.S. Bureau of Census population estimates were used as denominators.

Results. A total of 4,416 TBI deaths occurred in West Virginia in 1989–1998, for an annual average death rate of 23.6 per 100,000 population. From 1989 to 1998, TBI death rates declined 5% (p=0.4042). Seventy-five percent (n=3,315) of fatalities occurred among men. Adults ≥65 years of age accounted for the highest percentage of fatal injuries (n=1,135). The leading external causes of fatal TBI were: firearm-related (39% of reported fatalities), motor vehicles–related (34%), and fall-related (10%). Firearm-related TBI became the leading cause of TBI fatalities in 1991, surpassing motor vehicle-related TBI. Seventy-five percent of firearm-related TBI deaths were suicides (n=1,302). West Virginia's TBI death rate (23.6 per 100,000) was higher than the national rate (20.6 per 100,000). In 23 states, the average TBI death rates over the 10-year period were higher than West Virginia's. Whereas modest declines in TBI death rates occurred for motor vehicle-related and firearm-related causes in West Virginia, a concomitant 38% increase occurred in the fall-related TBI death rate during the decade.

Conclusion. Data presented in this report can be used to develop targeted prevention programs in West Virginia.

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Traumatic brain injury (TBI) is a major cause of mortality and morbidity in the United States. Published data indicate that 52,000 U.S. residents die from TBI-related causes every year[1] and that an estimated 80,000 to 90,000 U.S. residents are disabled annually as a result of TBI.[2] An estimated 5.3 million individuals live with permanent TBI-related disabilities.[3] Unintentional injury rates are very high in West Virginia;[4,5] however, studies have not examined the epidemiology of TBI in that state. Surveillance of serious injuries such as TBI could assist in the development of specific injury prevention measures. This study describes the epidemiologic characteristics of fatal TBI among West Virginia residents for the period 1989 through 1998.

METHODS

The National Center for Health Statistics (NCHS) Multiple Cause of Death data files were analyzed to identify residents of West Virginia who died of TBI from January 1, 1989, through December 31, 1998. The NCHS mortality data were compiled from death certificates filed directly from the vital statistics offices in the 50 states and the District of Columbia.

NCHS data were coded according to the International Classification of Diseases, Ninth Revision (ICD-9) codes[6] for cause of death, including underlying external cause of death. For the present study, a TBI-related death was defined as a death for which at least one TBI-associated diagnosis code was listed on the death certificate in the sequence of conditions contributing to death. TBI-associated diagnosis codes included the nature of death codes 800 (fracture of vault of skull); 801 (fracture of base of skull); 803 (other and unqualified skull fractures); 804 (multiple fractures involving skull or face with other bones); 850 (concussion); 851 (cerebral laceration and contusion); 852 (subarachnoid, subdural, and extradural hemorrhage following injury); 853 (other and unspecified intracranial hemorrhage following injury); 854 (intracranial injury of other and unspecified nature); 905.0 (late effects of fracture of skull and face); 907.0 (late effects of intracranial injury without skull fracture); and 873 (other open wound of head). The causes of TBI deaths were divided on the basis of the external cause of death (E-codes) into motor vehicle–related (E810–E825); fall-related (E880–E886, E888); firearm-related (E922, E955.0–E955.4, E965.0–E965.4, E970, E985.0–E985.4); or "other/unspecified" codes for cases with infrequent occurrence or of nonspecific nature.

Denominators for the calculation of rates were derived from the mid-year population estimates maintained by the Census Bureau for individual years of study.[7] Age-adjusted rates were standardized to U.S. Census population estimates for 2000 by the direct method. Appropriate 95% confidence intervals (CIs) were calculated for the rates based on the standard error that accounts for random variation in the number of deaths each year, as recommended by NCHS.[8] Poisson regression was used to determine the significance of the decline or increase in rates over the interval.[9] Using the same Multiple Cause of Death tapes, comparable age-adjusted fatal TBI data were determined for residents of the U.S., the 50 states, and the District of Columbia.

The Census Bureau has published data on land area, population, and population density for all states and the District of Columbia.[10] In 2000, Alaska had the lowest population density per square mile at 1.0, and the District of Columbia had the highest population density per square mile at 9,882.6.[10] The population density per square mile for West Virginia was 74.5. The Census data identified 25 states with lower population densities than West Virginia's, and the average TBI death rates of each of these states was compared with that of West Virginia.

Multiple Cause of Death tapes for 1999 and 2000 were not used in this analysis because the new ICD-10 coding scheme was used to code these data. Cause of death categories in the ICD-9 are different from those in the ICD-10, and a crosswalk between the coding schemes has not yet been developed. In addition, NCHS recommends that data from 1999 and beyond not be combined with previous years for trend analysis.[11]

RESULTS

A total of 4,416 TBI-associated fatalities occurred in West Virginia from January 1, 1989, through December 31, 1998, for an average annual death rate of 23.6 per 100,000 population (Table 1). This rate is almost 15% higher than the national average of 20.6 per 100,000. Nationally, TBI death rates declined 11.4%, from 21.9 per 100,000 to 19.4 per 100,000 (p=0.0001) during this interval. For West Virginia, however, TBI-related death rates declined 5%, from 24.0 per 100,000 to 22.8 per 100,000 (p=0.4042). A subgroup analysis of TBI death rates indicated that West Virginia rates were much higher than national rates in almost every gender, race, and age subgroup (Table 1).

TBI deaths by race, gender, and age group

Ninety-seven percent of West Virginia's TBI-associated deaths were among individuals identified as white (Table 1); 96% of West Virginia's population is white.[7] Unlike national rates, TBI death rates in West Virginia did not differ by race. In West Virginia and the United States, males were approximately four times as likely as females to die of a TBI (38.4 per 100,000 for males vs. 10.8 per 100,000 for females). The death rate among adults ages ≥65 years (41.5 per 100,000) was higher than the rate among other age groups. One out of every four fatal TBIs in West Virginia occurred among adults ages ≥65 years (Table 1).

Gender and major external causes of TBI death

The three leading causes of TBI-associated fatalities were: firearm-related (39%), motor vehicle-related (34%), and fall-related (10%) (Table 1). Firearms became the leading cause of TBI-associated deaths in 1991 (Figure). Eighty-six percent (n=1,485) of firearm-related TBI deaths were among males (16.9 per 100,000). Seventy-five percent (n=1,302) of firearm-related TBI deaths were suicides (6.9 per 100,000); 90% (n=1,176) of those firearm-related suicide deaths were among males. Overall, from 1989 to 1998, a nonsignificant decline occurred in the suicide-related TBI death rate (p=0.3901).

An average of 152 residents died of motor vehicle-related TBI annually, with 70% of these fatalities occurring among males. The rate of motor vehicle-related TBI declined 13% from 1989 through 1998 (p=0.0018) (Figure). In contrast,

Table 1. Number and annualized rate[a] of TBI-associated deaths in West Virginia and United States by selected characteristics, 1989–1998

	West Virginia			U.S.	
Variable	*Number (Percent)*	*Rate per 100,000*	*95% CI*	*Rate per 100,000*	*95% CI*
Year					
1989	444 (10)	24.0	21.8, 26.3	21.9	21.7, 22.1
1990	439 (10)	24.0	21.7, 26.2	21.7	21.5, 21.9
1991	472 (11)	25.5	23.2, 27.8	21.4	21.2, 21.6
1992	430 (10)	23.2	21.0, 25.5	20.3	20.2, 20.5
1993	471 (11)	25.1	22.8, 27.4	20.9	20.7, 21.0
1994	398 (9)	21.0	19.0, 23.1	20.7	20.5, 20.9
1995	440 (10)	23.4	21.2, 25.6	20.2	20.0, 20.3
1996	439 (10)	23.3	21.1, 25.4	20.0	19.8, 20.1
1997	450 (10)	23.8	21.5, 26.0	19.7	19.5, 19.8
1998	433 (10)	22.8	20.7, 25.0	19.4	19.3, 19.6
Race category (n=4,406[b])					
White	4,270 (97)	23.7	23.0, 24.4	20.1	20.1, 20.2
Black	136 (3)	23.2	19.2, 27.1	25.0	24.8, 25.2
Sex					
Female	1,101 (25)	10.8	10.2, 11.5	9.8	9.7, 9.8
Male	3,315 (75)	38.4	37.1, 39.7	33.0	32.9, 33.1
Major cause					
Falls	437 (10)	2.3	2.0, 2.5	2.1	2.1, 2.1
Firearms	1,726 (39)	9.2	8.8, 9.7	8.1	8.1, 8.1
Motor vehicles	1,518 (34)	8.2	7.8, 8.7	7.0	7.0, 7.0
Other/unspecified	735 (17)	3.9	3.6, 4.2	3.4	3.4, 3.4
Age group (years) (n=4,415[c])					
0–14	188 (4)	5.4	4.7, 6.2	5.5	5.5, 5.6
15–24	826 (19)	30.7	28.6, 32.8	27.5	27.5, 27.5
25–34	756 (17)	31.2	29.0, 33.4	23.0	22.9, 23.2
35–44	650 (15)	23.2	21.4, 25.0	18.8	18.7, 19.0
45–54	460 (10)	20.8	18.9, 22.7	28.8	28.5, 29.1
55–64	400 (9)	22.4	20.2, 24.6	11.6	11.4, 11.8
≥65	1,135 (26)	41.5	39.1, 43.9	37.2	37.2, 37.2
Total	4,416 (100)	23.6	22.9, 24.3	20.6	20.6, 20.7

[a]Rates are annualized for characteristics other than the year of death.

[b]Excludes 10 cases in which race was recorded as "other" or race was unknown.

[c]Excludes one case due to missing age information.

TBI = traumatic brain injury

fall-related TBI death rates increased 38%, from 2.1 per 100,000 in 1989 to 2.9 per 100,000 in 1998 (p=0.0531).

Age group and major external causes of TBI death

Marked differences are noted in the external causes of TBI death by age group (Table 2). For residents ages <35 years, the leading cause of fatal TBI was motor vehicle-related. Firearm-related incidents were the leading cause of TBI fatalities among people ages ≥35 years.

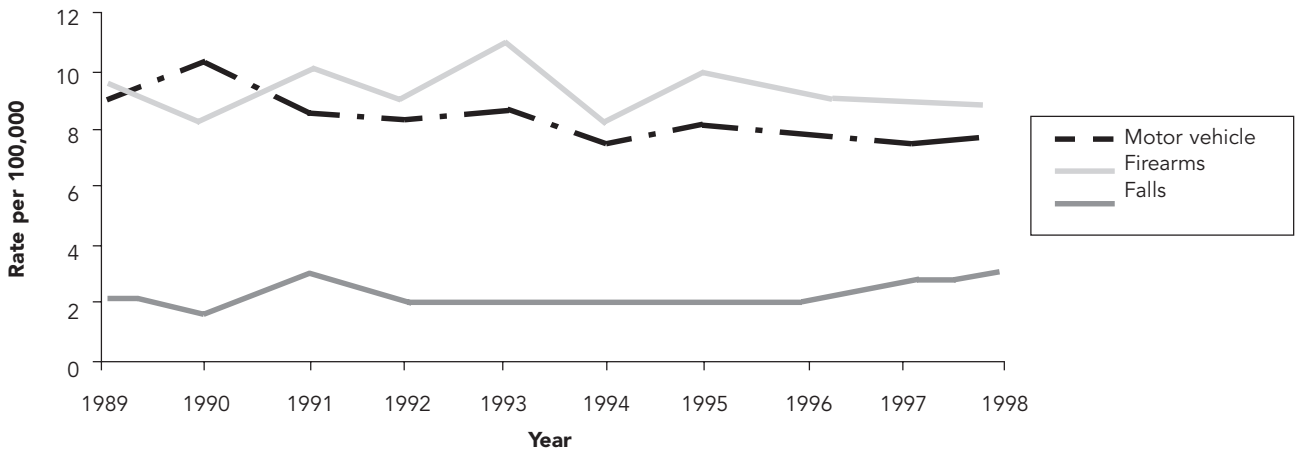
Trends in external cause of TBI-associated deaths

A moderate decline in rates of motor vehicle-related TBI occurred during the first five years of the study period (3.4%), and a moderate increase occurred in the later five years (2.7%) (Table 3). The increase in the rate for firearm-related TBI from 1989 to 1993 (14.9% increase) was higher than the increase from 1994 to 1998 (3.7%). The increase in the rate of fall-related TBI was apparent only between 1994 and 1998, and this increase was significant (p=0.0276).

Comparison of average TBI death rates by states, 1989–1998

Table 4 presents annualized age-adjusted TBI-associated death rates by state. The highest TBI-associated death rate was in Wyoming (36.3 per 100,000), and the lowest rate was in Massachusetts (9.2 per 100,000). Twenty-three states had

Figure. TBI-associated death rates by external cause, West Virginia, 1989–1998



SOURCE OF DATA: National Center for Health Statistics Multiple Cause of Death public use data files.

TBI = traumatic brain injury

higher average TBI-associated death rates than West Virginia. Twenty-five states have lower population densities per square mile than West Virginia; 15 (60%) of these 25 states had higher TBI-associated death rates than West Virginia.

DISCUSSION

The average annual TBI-associated death rate among West Virginia residents exceeded the national rate during the 10-year period 1989–1998. Despite recent overall declines in TBI-associated death rates nationally, these rates remain high in West Virginia and other rural states. Higher rates of TBI in rural areas had previously been reported.[12] Similarly, rates among most sex, race, and age group categories were higher in West Virginia than in the U.S. as a whole.

While recent data indicate significant decreases in fatal firearm-related injuries,[13] fatal TBI caused by firearm-related suicide remains a major problem in West Virginia, representing 30% of TBI-related fatalities. Although our knowledge of effective suicide prevention methods is limited,[14] studies have shown that a recent purchase of a handgun[15] and the availability of guns at home[16,17] increase the risk of suicide. An ecological study describing gun safety laws showed that states with gun safe-storage laws experienced lower than expected unintentional firearm-related deaths,[18] but the extent to which gun safety laws prevent TBI-related suicides, especially in rural communities, is yet to be determined. Further research is needed to understand the circumstances of TBI-related suicides and to develop or deploy appropriate intervention strategies.

Motor vehicle-related TBI prevention efforts should focus on people in the 15–34 year age group. Data from the Centers for Disease Control and Prevention showed that during the study period, the age-adjusted unintentional motor vehicle-related death rate for the 15–34 year age group in West Virginia was 65% higher than the statewide average

Table 2. Number and annualized rate[a] of TBI-associated deaths by age group and external cause of death, West Virginia, 1989–1998

	Age group (years)													
	0–14		*15–24*		*25–34*		*35–44*		*45–54*		*55–64*		*≥65*	
External cause	*Number*	*Rate*	*Number*	*Rate*	*Number*	*Rate*	*Number*	*Rate*	*Number*	*Rate*	*Number*	*Rate*	*Number*	*Rate*
Falls	2	—	11	—	22	0.9	28	1.0	37	1.7	54	3.0	283	10.3
Firearms	31	0.9	315	11.7	325	13.4	316	11.3	206	9.3	193	10.8	340	12.4
Motor vehicles	119	3.4	449	16.7	339	14.0	205	7.3	139	6.3	83	4.7	184	6.7
Other/unspecified	36	1.0	51	1.9	70	2.9	101	3.6	78	3.5	70	3.9	328	12.0

NOTE: n=4,415. Information on age group or external cause was missing for one case.

[a]Rate per 100,000 population. Rates are not shown where cell count is <20.

TBI = traumatic brain injury

Table 3. Comparison of percent change in TBI-associated death rates per 100,000 population, 1989 to 1993 vs. 1994 to 1998, by external cause, West Virginia and U.S.

	1989–1993				*1994–1998*			
Cause	*1989 rate*	*1993 rate*	*Percent change in rate, 1989 to 1993*	*p-value*[a]	*1994 rate*	*1998 rate*	*Percent change in rate, 1994 to 1998*	*p-value*[a]
Motor vehicles	8.8	8.5	–3.4	0.2455	7.5	7.7	+2.7	0.9075
Firearms	9.4	10.8	+14.9	0.0785	8.2	8.5	+3.7	0.8841
Falls	2.1	2.1	0	0.8133	2.1	2.9	+38.0	0.0276
West Virginia total	24.0	25.1	+4.6	0.5851	21.0	22.8	+8.6	0.1954
U.S. total	21.9	20.9	–4.6	0.0001	20.7	19.4	–6.3	0.0001

[a]*p*-value for trend.

TBI = traumatic brain injury

(37.3 per 100,000 vs. 22.5 per 100,000), and 47% higher than the national rate for the same age group (37.3 per 100,000 vs. 25.3 per 100,000).[5] Motor vehicle-related causes have accounted for the majority of unintentional injury deaths for many years.[5] There are effective intervention strategies to prevent motor vehicle-related injuries, including primary enforcement restraint laws, graduated licensing of new drivers, and community-based health education campaigns.[19–21] Currently, West Virginia has a secondary enforcement occupant restraint law, which means a police officer

Table 4. Age-adjusted annualized TBI-associated death rates per 100,000 population for 1989–1998 and population density per square mile for 2000, 50 U.S. states and District of Columbia

State	*TBI rate per 100,000 population*	*Population density*	*State*	*TBI rate per 100,000 population*	*Population density*
Wyoming	36.3[a]	4.7	Kansas	21.9[a]	30.3
Montana	32.3[a]	5.5	Vermont	21.7[a]	60.8
District of Columbia	31.7	9,882.6	Nebraska	21.6[a]	20.5
Mississippi	30.9[a]	54.9	Indiana	21.5	154.6
Nevada	30.4[a]	10.9	Virginia	21.2	156.3
Louisiana	29.6	96.9	Florida	21.1	239.6
Arkansas	29.3[a]	45.1	Wisconsin	19.4	90.1
Idaho	29.2[a]	12.2	Maine	19.2[a]	39.8
Alabama	29.0	79.6	North Dakota	19.0[a]	9.3
South Carolina	26.9	115.8	Ohio	19.0	264.9
New Mexico	26.8[a]	12.5	Iowa	18.9[a]	49.7
Oklahoma	26.8[a]	45.8	Delaware	18.8	340.8
Georgia	26.6	111.9	Michigan	18.5	163.6
Oregon	26.5[a]	29.6	Pennsylvania	18.5	265.1
Missouri	26.4[a]	74.3	California	18.3	190.8
Colorado	25.6[a]	31.8	Illinois	16.9	205.6
Arizona	25.2[a]	32.3	Minnesota	16.8[a]	55.0
Tennessee	25.2	118.3	New York	16.1	381.0
Alaska	25.1[a]	1.0	Maryland	15.7	489.2
South Dakota	24.9[a]	9.2	New Hampshire	15.6	123.7
North Carolina	24.8	136.1	Hawaii	14.5[a]	29.9
Utah	24.4[a]	21.0	Connecticut	13.4	678.4
Kentucky	24.3	92.8	New Jersey	12.6	1,042.0
West Virginia	23.6	74.5	Rhode Island	11.6	960.3
Texas	22.9[a]	64.9	Massachusetts	9.2	767.6
Washington	22.6[a]	73.1			

SOURCES OF DATA: National Center for Health Statistics Multiple Cause of Death data files, 1989–1998, and Reference 10.

[a]Lower population density per square mile than West Virginia's

must stop motorists for other violations before enforcing safety belt use and child restraint use laws.[22] In comparison to secondary restraint laws, primary enforcement laws have been shown to result in a reduction in fatal injury rates[23] and an increase in safety belt use rates.[24] An additional approach that could be used to reduce motor vehicle–related injuries is the application of effective community-based interventions, such as sobriety checkpoints and educational components to reinforce the implications of drunk driving.[20]

The 38% increase in TBI fall-related deaths, with the largest increase seen in the older population, is a major highlight of this research. Some of the increase might be attributable to more complete TBI diagnosis in older adults because of greater use of brain imaging procedures.[25] Factors such as medication use, co-morbid conditions, health behaviors, and hemorrhagic complications of TBI (e.g., anticoagulant or platelet-inhibiting medications)[26–31] might also play a role in the increase. Despite our knowledge of environmental and host risk factors for falls, better understanding of the circumstances and risk factors among rural residents could further aid in the development of effective interventions for older adults. A multifactorial approach, including a combination of adjustment in medications, behavioral instructions, and exercise programs aimed at modifying risk factors, has been recommended to reduce the risk of falling in the older population.[31–33]

Compared with urban residents, rural residents have higher injury-related mortality rates overall[34,35]—despite indications from published data that many rural trauma deaths are preventable.[36] Research has demonstrated that inappropriate care rendered in rural settings during the emergency department phase of treatment contributes to these deaths and that educating primary care providers in basic principles of patient stabilization and initial treatment is essential to reduce these preventable deaths.[36] However, other factors such as emergency medical service quality and response and transport times might be associated with high injury-related mortality in rural areas.[37,38]

Traditionally, strategies to prevent TBI have focused exclusively on specific causes and risk groups.[2] In rural areas, broader issues of patient transportation and acute care and emergency medical services must also be addressed. Severely injured individuals in remote, less densely populated areas,[36–39] such as many parts of West Virginia, often travel long distances to major trauma centers, sometimes in hazardous weather conditions over mountainous terrain. As a result, they might not survive to be treated in a trauma center. In addition, there might be limited medical personnel and resources available to stabilize these patients in remote area hospitals.[40–42] Recognizing several factors relating to the survival of rural residents following trauma (e.g., long transport times, inadequate training of prehospital personnel, fewer available physicians, and limited exposure of providers to trauma patients, which can influence provider skills),[43] the American College of Surgeons has issued a statement acknowledging that improving the care of trauma patients in rural environments is a major public health concern that must be addressed through treatment, intervention, and research programs.[44]

There are several limitations to this study. First, TBI deaths were identified by diagnosis codes listed in the sequence of events leading to death. The accuracy and reliability of codes are dependent on accurate diagnoses and on the care with which these diagnoses are recorded on death certificates by physicians, medical examiners, or coroners.[45] The quality of medical certification of TBI on death certificates has not been fully evaluated.[45] In addition, because TBI-related deaths were selected from cases in which at least one TBI diagnosis code was included in the sequence of conditions leading to death, not all of the deaths that are associated with TBI constitute deaths that are actually due to TBI.

The lack of narrative text in the NCHS Multiple Cause of Death mortality data also presents a limitation because circumstances contributing to injury might not be recorded. The original death certificate does include a narrative describing the injury; however, the narrative is not retained on the public use dataset. Finally, the present study focused only on TBI deaths, but the public health impact of TBI hospitalizations, emergency department visits, and the resulting disability among those who survive is important to consider. Further studies of TBI morbidity are needed to truly understand the impact of TBI in West Virginia.

TBI-related deaths represent one of every three injury-related deaths in West Virginia.[5] In this study, we identified etiologic factors that can be used to set TBI prevention priorities, allocate resources, and evaluate interventions. These findings demonstrate the continued need for focused prevention efforts, e.g., interventions to reduce falls in the older population. The effects of patient transportation and acute care and emergency medical services in rural areas on TBI-associated mortality should be evaluated.

This article is dedicated to the memory of Dr. Adekoya's mentor, Derek Dunn, PhD, of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention [1945–2002].

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