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Years of Life Lost Because of Gunshot Injury to the Brain and Spinal Cord

ABSTRACT

Richmond TS, Lemaire J: Years of life lost because of gunshot injury to the brain and spinal cord. Am J Phys Med Rehabil 2008;87:609–618.

Objective: A recent study (Lemaire) estimated the life expectancy loss attributable to gun deaths at 103.6 days for the overall U.S. population: 150.7 days for white males and 361.5 days for black males. This study estimates the life expectancy loss attributable to the premature death of individuals who initially survived gun-related traumatic brain injury (TBI) and spinal cord injury (SCI) in the United States.

Design: Interpersonal TBI data were drawn from a surveillance system, and self-inflicted TBI data were obtained from the Web-based Injury Statistics and Reporting System. SCI data were obtained from a national database. Multiple decrement analysis was used to calculate the days of life lost to gunshot wounds to the brain and spinal cord, by race and gender, in the United States.

Results: On average, across age, gender, and race, life expectancy in the United States is reduced by 3.1 days because of the shorter lifespan for individuals who survive an initial gunshot wound to the brain or spinal cord. Black males bear a disproportionate burden, losing 9.5 days, whereas white males lose 4.6 days. Black and white females lose 1.5 and 1.0 days, respectively.

Conclusions: We add these findings to the Lemaire study, resulting in a total of 106.7 days of life expectancy loss from gunshot wounds for the U.S. population, with 371.0 days of life lost for black males.

Key Words: Life Expectancy, Brain Injuries, Spinal Cord Injuries, Wounds, Gunshot

CME Objectives:
On completion of this article, the reader should be able to (1) discuss the effect that level of injury has on loss of life expectancy after gun-related spinal cord injury, (2) describe the effects that gender and race have on additional life expectancy loss after gun-related spinal cord and brain injury, and (3) describe the additional loss of life expectancy attributable to gun-related spinal cord injury and traumatic brain injury in the United States.

Level: Advanced.

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Disclosures:

The authors are fully responsible for the life expectancy analysis provided in this paper. The following centers provided data on age, gender, and race for injuries presented in Tables 1–3 in this paper. TBI data were provided by the TBI National Data Center, which is funded by grant H133A011403 from the National Institute on Disability and Rehabilitation Research, Department of Education. SCI data presented in Tables 2 and 3 were provided by the National Spinal Cord Injury Statistical Center, which is funded by grant H133N50009 from the National Institute on Disability and Rehabilitation Research, Office of Special Education and Rehabilitative Services, U.S. Dept of Education, Washington, DC. Funding for data acquisition was provided by the Firearm and Injury Center at Penn, through funding by the Joyce Foundation.

The United States is a society in which guns are legally available to its citizens, with the exception of certain groups (i.e., felons, mentally ill, and juveniles). Handguns are prevalent in the United States, which is said to have more handguns in circulation than 24 other industrialized nations combined.[1] Gunshot wounds (GSW) account for a large proportion of the burden of injury in the United States, where they are the second-leading cause of injury death.[2] Given that guns are readily accessible (both legally and illegally)[3] and their contribution to lethality, we undertook this study to estimate the impact on U.S. life expectancy of premature death from GSW to the brain and spinal cord in persons who survived the initial injury.

Life expectancy is one marker of the quality of health of a country's citizens. The United States is widely recognized as a leading superpower in the global context. Despite this status, and despite the fact that 15.3% (the largest percentage in the world)[4] of the gross domestic product is dedicated to the health of its citizens, U.S. life expectancy ranked only 48th among the 224 countries, territories, and possessions of the world in 2006.[5] Examining the causes of mortality that contribute to lower life expectancy is important in the face of this apparent mismatch of resource richness and life expectancy. In 2005, Lemaire[6] examined the contribution of gun-related deaths to life expectancy in the United States. He showed that the average American loses 103.6 days of life to gun violence. This reduction in life expectancy attributable to gun violence accounts for 26.9% of the male life expectancy gap between the United States and other developed nations, and 3.3% of the female gap. He found that males lost 166.8 days to GSW, which exceeds the combined life expectancy losses for males from colon cancer (63.3 days) and prostate cancer (46.5 days) combined. He also found substantial racial disparity within the United States, with the life expectancy loss for white males being 150.7 days, but 361.5 days for black males.

The Lemaire calculations considered only gun-related deaths and did not account for the premature mortality of individuals who initially survived serious gun-related injuries, specifically GSW to the brain and GSW to the spinal cord. There are approximately 1.4 million traumatic brain injury (TBI) visits to the emergency department annually, of which 235,000 are hospitalized, 49,900 die, 439,000 are treated in offices, and 89,000 are treated in outpatient settings.[7] It is estimated that 6% of all TBI hospitalizations are attributable to assault,[7] and GSW account for 6% of all assaults,[8] resulting in a substantial number of GSW cases to the brain. Spinal cord injury (SCI) affects fewer Americans, with 11,000 new cases estimated to occur each year.[9] GSW accounts for 17.5% of male SCI and 16.2% of female SCI.[10] Compared with the general population, the life expectancy of survivors with all-cause SCI and TBI is significantly reduced.[11,12] It is likely that, together, TBI and SCI contribute an additional loss of life expectancy from GSW injury that has not been captured previously. Therefore, we undertook this study to estimate the additional loss of life expectancy attributable to gun-related SCI and TBI in the United States.

METHODS

Data Sources and Procedure

Interpersonal TBI

Source data for interpersonal TBI by gun are from a federally funded surveillance system based in 14 states.[7] All participating state health departments used the same guidelines to identify TBI cases from hospital discharge data or statewide injury data systems. Data include all GSW to the brain as of March 2006 with complete 2-yr follow-up data. To avoid possible double counting, we did not include in-hospital deaths, which we assumed were captured by the Web-based Injury Statistics and Reporting System (WISQARS)[13] data system used in the original Lemaire paper. Our analyses focus on the 235,000 TBI patients who were hospitalized and discharged alive. We chose not to include TBI cases of lesser severity (i.e., patients who were not hospitalized) because we assumed that these minor injuries would not result in premature mortality. The effect of these assumptions is conservative, in the sense that the numbers of days of life expectancy lost will be slightly underestimated, rather than overestimated.

The TBI surveillance system estimates that interpersonal violence (assaults) accounts for 14,000 hospitalizations each year[7] and categorizes them by age, gender, and race.[8] We assumed that the age distribution attributable to assault is independent of race, and that the age, gender, and racial distributions of TBI from GSW are the same as the corresponding distribution of TBI attributable to assault. Because GSW accounts for 6% of all assaults in the United States, we estimate that 840 persons suffer interpersonal TBI from GSW every year in the United States. The resulting estimated distribution by age, gender, and race is presented in Table 1.

Self-Inflicted TBI

Because the surveillance system does not specify self-inflicted TBI, we estimated the number and distribution of self-inflicted TBI from death data and case fatality rates. Source data for the distribution of age, race, and gender of self-inflicted TBI were obtained from WISQARS[13] and indicate that 16,586 persons completed gunshot suicide in 2000 in the United States. The vast majority of self-inflicted GSW are to the brain.[14] The majority of these deaths was male (14,454). Shenassa et al.[15] indicate that 96.5% of male and 96% of female suicides by gun are completed. This allows us to estimate that 613 individuals (524 males and 89 females) survived self-inflicted GSW to the brain in the United States in 2000. There are variations in the proportion of suicides by gun that are completed, ranging from 82.5% to the 96.5% reported by Shenassa and colleagues.[16,17] Again, we use the most conservative case fatality rates, resulting in a possible underestimation. The resulting estimated distribution by age, race, and gender is presented in Table 1.

SCI

Source data for SCI were obtained from a national database that has collected extensive data

TABLE 1 Age, race, and gender distribution of traumatic brain injury (TBI) and spinal cord injury (SCI) from gunshot wounds in the United States

Age, yrs	Total	White Male	White Female	Black Male	Black Female	Other
Interpersonal GSW to brain						
0–4	44.3	15.8	9.9	9.7	5.7	3.2
5–14	20.7	10.2	1.8	6.2	1.0	1.5
15–19	97.8	51.2	5.7	31.3	3.3	6.3
20–24	108.8	56.9	6.3	34.8	3.7	7.1
25–34	206.9	103.0	17.2	63.0	9.9	13.8
35–44	207.4	101.4	19.2	62.0	11.1	13.7
45–64	125.0	62.5	10.1	38.3	5.9	8.2
>65	29.0	10.4	6.5	6.3	3.8	2.0
Total	840.0	411.3	76.8	251.7	44.4	55.8
Self-inflicted GSW to brain						
0–14	4.1	3.1	0.7	0.2	0	0.1
15–24	83.4	61.4	7.7	10.2	1.1	3.0
25–34	90.8	65.8	11.8	8.7	1.3	3.2
35–44	118.6	88.2	20.9	6.1	1.0	2.4
45–54	106.1	82.0	17.5	4.1	1.0	1.5
55–64	67.9	53.6	10.5	2.2	0.4	1.2
>65	142.2	125.1	12.5	3.4	0.3	0.9
Total	613.1	479.3	81.7	35.0	5.2	11.9
GSW to spinal cord						
0–14	41.9	19.0	9.4	4.6	2.0	6.8
15–24	723.5	404.7	84.2	131.6	16.2	86.8
25–34	461.4	248.0	48.6	91.0	15.7	58.1
35–44	275.4	148.0	36.9	53.7	10.9	25.9
45–54	172.3	93.2	23.8	38.9	5.6	10.8
55–64	116.6	64.0	16.7	23.9	4.2	7.8
>65	107.0	57.5	24.0	16.1	4.8	4.6
Total	1898.1	1034.4	243.7	359.8	59.4	200.8

about SCI since 1973.[10] This system captures approximately 13% of the new cases of SCI in the United States annually. This data source is not a random sample; instead, it captures cases managed at one of the 16 federally funded Model Spinal Cord Injury Care Systems.[18] Males account for the majority of SCI (81.2%); 17.5% of SCI in men and 16.2% of SCI in women result from gunshot injuries to the spinal cord.[10] Thus, we estimate that 1898 individuals (1563 males and 335 females) survive gun-related SCI each year in the United States [(8932 × 0.175) + (2068 × 162) = 1898; Table 1]. We assumed distribution of cases and life expectancy loss across severity and age groups to be independent of gender.

To more fully understand how life expectancy varies by the functional status of these SCI survivors, we obtained data for the level of the neurological lesion for all SCI resulting from gunshot injury from the National SCI Statistical Center. These data reveal that 74.2% of SCI from gunshot injury are paraplegic, defined as lesions of the thoracic, lumbar, or sacral regions of the spinal cord with paresis or paralysis of the lower body. The remaining cases (25.8%) are quadriplegic, defined as lesions of the cervical spinal cord, leading to paresis or paralysis of both arms and legs. Ventilator-dependence cases at hospital discharge occurred in 0.7% of paraplegic cases and in 6.1% of quadriplegic cases.

Statistical Analysis

GSW to the Brain

Disability, in particular immobility, has been strongly related to higher mortality after TBI.[19] Shavelle and colleagues[20] developed life expectancy tables based on six levels of disability: persistent vegetative state; cannot walk and must be fed by others; cannot walk and feeds self; some walking ability and must be fed by others; some walking ability and feeds self; and walks alone. We constructed similar outcome categories within the limitations of the data available from the national TBI surveillance system, which provides disability status at rehabilitation discharge and at 1 and 2 yrs after injury for persons sustaining TBI attributable to assault. At discharge from inpatient rehabilitation, nearly 35% could walk alone, whereas 32% could not walk at all. About 15% could not feed themselves. We calculated the proportion of TBI attributable to GSW in each functional category, by age group and gender, and then we applied these data to the Shavelle life expectancy tables to calculate the days of life expectancy loss for interpersonal GSW to the brain. We then used multiple decrement analysis,[21] an actuarial technique that allows the examination of competing causes of death, to calculate the number of days of life lost to GSW to the brain in the U.S. population, by race and gender.

GSW to the Spinal Cord

The National SCI Data Center provided explicit data about life expectancy for SCI patients who were alive at 24 hrs after gunshot injury to the spine. These data enabled us to estimate the life expectancy in survivors of GSW to the spinal cord, as a function of age and neurological status–weighted averages[10] (Table 2). For individuals who survive the initial injury, death most likely results

TABLE 2 Life expectancy in survivors of gunshot wounds to the spinal cord in the U.S. by age and neurologic status in years

		Life Expectancy Loss, yrs			
Age, yrs	Frequency, No. of People	Paraplegic	Quadriplegic	Ventilator Dependent	Average Life Expectancy Loss
10–14	220	12.8	19.8	44.4	15.5
15–19	2251	12.7	19.5	43.6	15.3
20–24	5146	12.4	18.8	41.5	14.9
25–29	3707	12.1	18.2	38.9	14.4
30–34	2756	11.8	17.7	36.6	14.0
35–39	1957	11.6	17.2	34.5	13.7
40–44	1602	11.1	16.5	32.1	13.1
45–49	1285	10.8	15.7	29.5	12.6
50–54	1003	10.2	14.8	26.6	11.9
55–59	849	9.6	13.7	23.6	11.1
60–64	692	8.9	12.5	20.5	10.2
65–69	541	8.0	11.1	17.5	9.1
70–74	371	7.1	9.6	14.5	8.0
75–79	318	6.1	8.2	11.4	6.8
>80	293	5.2	6.8	8.7	5.7

from complications of the SCI.[22–24] Therefore, we also used multiple decrement analysis to calculate the number of days of life lost to GSW to the spinal cord, by race and gender, in the United States.

Multiple decrement theory is the statistical technique that actuaries use to calculate life expectancy losses, and it is used widely in human actuarial research.[21] Using this technique, we first use a U.S. life mortality table that includes all causes of death. From this table, the deaths from GSW to the brain and spinal cord are removed, to get a table without the GSW deaths; life expectancy is then recalculated. These calculations take into consideration that when someone does not die from GSW to the brain and spinal cord, he or she will die from another cause; multiple decrement technique properly accounts for this in the analysis.

RESULTS

Interpersonal GSW to the Brain

The reduction in life expectancy experienced by individuals with TBI from GSW varies by intent, age, and severity of the injury. As stated earlier, calculations were based on life expectancy tables developed by Shavelle and colleagues,[20] as applied to the data acquired from the National TBI Data Center. Overall, premature mortality in individuals surviving interpersonal GSW to the brain accounts for 0.5 days lost for the U.S. population, with the greatest loss occurring in black males (2.2 days) (Table 3).

Self-Inflicted GSW to the Brain

With gun-related suicide data and case fatality ratios, we estimate that 613 individuals survived gunshot suicide attempts in 2000. On the basis of the distribution by age and gender, we calculated that the number of days of life expectancy loss for self-inflicted GSW to the brain was 0.4 days in 2000 for the U.S. population, with white males bearing the largest loss, at 0.7 days (Table 3).

GSW to the Spinal Cord

Table 3 presents life expectancy loss as a function of age and neurological level for individuals alive at 24 hrs after injury. Averaging over age groups, the life expectancy loss for each person with quadriplegia is 17 yrs, and, for each person with paraplegia, it is 11.4 yrs. This loss in life expectancy increases to 35 yrs for those individuals who are dependent on a ventilator. Multiplying these losses by the number of new cases occurring each year, we find that, each year, 25,647 yrs of life are lost because of new GSW to the spinal cord.

Translating this into a population estimate of life expectancy loss for GSW to the spine, we find that GSW accounts for 2.3 days of life lost (Table 3). Black males account for the most days of life expectancy loss (7.0 days), followed by white males (3.4 days).

Total Reduction in Life Expectancy

Summing the results, we find that, on average, life expectancy in the United States is reduced by 3.1 days because of the shorter life span for individuals who survive initial GSW to the brain and spinal cord (Table 3). Black males bear a disproportionate burden, losing 9.5 days, whereas white males lose 4.6 days. We add these findings to the original calculations of loss of life expectancy as presented in the Lemaire paper, resulting in a total of 106.7 days of life expectancy loss from GSW for the U.S. population, with 371.0 days of life lost for black males (Table 3).

DISCUSSION

The worldwide burden of injury has been examined using a variety of methods. Examination of cause-specific mortality rates is one way to estimate the burden of injury on a society,[25,26] but it does not fully account for the impact of injury morbidity. Other approaches include the use of years of life lost attributable to premature mortal-

TABLE 3 Total reduction (days) in life expectancy from gunshot wounds (GSW)

Group	Interpersonal GSW to Brain	Self-Inflicted GSW to Brain	GSW to Spinal Cord	Total Brain and Spinal Cord	Deaths[a]	Total
U.S. population	0.5	0.3	2.3	3.1	103.6	106.7
Males	0.8	0.5	3.8	5.1	166.8	171.9
Females	0.2	0.1	0.8	1.1	30.5	31.6
White males	0.6	0.6	3.4	4.6	150.7	155.3
White females	0.1	0.1	0.8	1.0	31.1	32.1
Black males	2.2	0.3	7.0	9.5	361.5	371.0
Black females	0.4	0.0	1.1	1.5	44.6	46.1

[a] From Lemaire.[6]

ity, years lived with a disability, disability-adjusted life years, and healthy life years lost.[27,28] The strength of multiple decrement analysis, which we use in our analysis, is that it is the only technique that properly accounts for competing causes of death. In contrast, years of life lost attributable to premature mortality does not take into account the fact that GSW survivors could die from other causes (e.g., cancer, heart disease), and, thus, the loss resulting from one gun death is overestimated.[29]

The burden of traumatic brain and SCI in terms of complications, disability, and lower quality of life is well known. In this paper, we extend the knowledge on the burden of traumatic brain and SCI from gunshot injury by estimating the premature mortality of survivors of GSW to the brain and spinal cord and by examining the disproportionate burden borne by segments of the U.S. population. GSW contribute to the life expectancy disparity found between the United States and other industrialized nations. This disparity seems to be related to the widespread availability of guns in the United States. Of great concern is the disproportionate effect that GSW have on life expectancy for black males, accounting on average for more than 1 yr of loss. This finding provides additional evidence that firearms take a substantial toll on U.S. society.

This follow-up analysis indicates that 3.2 additional days are lost from GSW to the brain and spinal cord for those individuals who initially survive. At first, the further reduction may seem an insignificant addition to the original calculation of 103.6 days. However, it is substantial when compared with other causes of life expectancy loss, such as machinery deaths (2.1 days) or adverse effects from medical care/drugs (6.3 days).[6]

These findings should be interpreted with caution, given the limited specificity of available data for delayed mortality from TBI and SCI. Lack of data forced several assumptions in our calculations. Our calculations for TBI may be underestimated on the basis of our assumption that less severe injuries would not affect life expectancy. Finally, we did not include any in-hospital TBI deaths, which we assumed were already captured in Lemaire's initial paper via WISQARS, to avoid the risk of double counting those deaths.

Some experts believe that the incidence of SCI represents a substantial underreporting because no study of SCI incidence has been conducted since the 1970s. We have had to assume that the annual number of new SCI cases has been relatively stable since the 1970s, at 11,000, and that the 13% of new SCI cases captured annually by the national SCI database are representative of all SCI cases. In addition, 27.8% of cases lost to follow-up have unknown survival statuses, and, thus, we assumed that the lost cases were distributed across all categories in the same way as successfully followed patients. It is likely, however, that a significant number of patients were lost to follow-up because they died, resulting in an underestimation of mortality rates. We did not take into consideration socioeconomic status, level of community integration, or preinjury health status, which have been shown to have small but statistically significant effects on mortality after SCI.[30] Finally, we assumed that the distribution of SCI attributable to GSW (i.e., quadriplegic, paraplegic) was the same as for all violent acts.

In this paper, we focus on average life expectancy reduction as a specific consequence of GSW to the brain and spinal cord. There are other substantial consequences. Consequences of GSW injury to the central nervous system include the high cost of care for SCI, with 50% of these costs passed to taxpayers via the Medicaid program. These costs are substantial, with the lifetime cost for a 25-yr-old with high quadriplegia (C1–C4) estimated at $2.9 million, lower quadriplegia (C5 and below) at $1.6 million, and $0.9 million for paraplegia (in 2006 dollars).[23] The cost escalates when factoring in lost wages, fringe benefits, productivity, the lower quality of life, and the social and emotional costs to patients (e.g., higher suicide rates), their families (e.g., lower marriage rates and higher divorce rates), the health care system, and society at large.

CONCLUSION

The burden of traumatic brain and SCI to individuals, families, and communities has been broadly studied, and the impact is great. In this paper, we have demonstrated the substantial reduction in life expectancy that is added to by the premature deaths in those who initially survive GSW to the brain and spinal cord. This additional reduction is borne disproportionately by males and, in particular, black males. These findings confirm that the presence and use of firearms have an impact on the health and longevity of citizens in the United States.

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CME Self-Assessment Exam Questions

CME Article Number 7: *T.S. Richmond, et al.*

1. Which of the following accurately reflects the U.S. life expectancy in relation to other countries in the world?
   A. 15th.
   B. 36th.
   C. 48th.
   D. 64th.
2. Life expectancy loss due to gun shot wound for men exceeds the combined life expectancy loss of which of the following:
   A. Lung and colon cancer.
   B. Heart disease and stroke.
   C. Motor vehicle crash and falls.
   D. Colon and prostate cancer.
3. Which of the following techniques, used in this study, fully accounts for competing causes of death?
   A. Years of life lost due to premature mortality.
   B. Multiple decrement analysis.
   C. Healthy life years lost.
   D. Disability adjusted life years.
4. Life expectancy for individuals who survive an initial gun shot wound to the brain and spinal cord is reduced by?
   A. 3.1 days.
   B. 5.2 days.
   C. 6.4 days.
   D. 8.8 days.
5. Which of the following groups bears a disproportionate burden of life expectancy loss due to death by gun shot?
   A. White males.
   B. White females.
   C. Black males.
   D. Black females.

The **answers** to any essay questions must be typed or computer printed on a separate piece of paper and attached to this page.

After finishing this exam:

1. Check your answers with the correct answers on page 653.
2. Photocopy and complete the CME Evaluation and Certification on the next page and mail to CME Department, AAP National Office, 1106 N. Charles Street, Suite 201, Baltimore, MD 21201.
3. This educational activity must be completed and postmarked by December 31, 2009. **AAP Members** may complete and submit this CME Answering Sheet and the following CME Evaluation and Certification page online through the members-only section of the AAP web page at www.physiatry.org.

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Circle the appropriate answers.

1.	A	B	C	D
2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D

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Suggestions for future topics:? ____

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