ESTIMATED UNITED STATES INCIDENCE OF DISABLING AND FATAL CENTRAL NERVOUS SYSTEM TRAUMAS: A NEED TO RE-EVALUATE PRIORITIES?

Thomas E. Anderson and David C. Viano
Biomedical Science Department
General Motors Research Laboratories
Warren, MI 48090-9058
U.S.A.

Abstract

Of approximately 425,000 brain injuries from all causes of trauma estimated to have occurred in the United States in 1984, about 329,000 experienced good recovery with minimal or no deficit. Fatalities accounted for 71,000 (about 70% dead on arrival, 30% after admission to a hospital), leaving 25,000 experiencing long-term neurologic sequelae ranging from coma to memory deficits. Since as many as 10% of those classified as good recovery exhibit psychological or cognitive deficits which may affect employment or quality of life, the total incidence of individuals suffering serious functional loss due to brain injury may be as high as 58,000 annually. Brain injuries contribute significantly to fatalities and disabilities resulting from crash injury. In 1984, car, truck and bus occupants sustained 29.8% of all brain injuries, suggesting a total of 21,000 fatal brain injuries to occupants, or almost 60% of all 1984 fatalities reported for vehicle occupants.

While only 12,500 acute spinal cord injuries were estimated to occur in the United States for 1984, fewer than 1% of those injuries were projected to experience good recovery. Since about 4,700 were dead on arrival and another 1,300 died after admission to a hospital, an estimated 6,500 cases of neurologic impairment resulted. Approximately 37% of all spinal cord injuries are to car, truck or bus occupants.

Our analysis of these historical data shows that although the incidence of brain injury from all causes is thirty-four times that of spinal cord injury, many of the brain injuries carry little or no long-term consequence. Since good recovery occurs in fewer than 1% of those with spinal cord injury, the incidence of permanent disability from spinal cord injury equals 25% of the incidence of total disability after brain injury. Even if all potential mild disability cases are included for brain injury, the incidence of spinal cord disability is approximately 11% that resulting from brain injury. These data suggest that spinal cord injuries contribute proportionately more to long-term disability than implied by hospital admission data alone relative to brain injury. These data should be carefully considered in setting priorities for occupant protection and crash injury prevention.

INTRODUCTION

Heart disease, cancer and stroke are major causes of death and disability in the United States; however, contrary to popular belief, accident injury is an equal or greater contributor of lost years of productive life.(4, 7, 16, 20, 21) Accidents are the fourth leading cause of death, and account for 5.5% of all U.S. fatalities, primarily affecting the young adult, as shown in Figure 1.(4) Over half the accident fatalities are from injuries sustained in motor vehicle crashes (Figure 2A), with smaller fractions from falls and other causes. Motor vehicle accidents are the leading cause of death for people under the age of 45, and account for nearly 55% of deaths for people 15-24 years old.(4)

Since accidents predominantly affect young adults they are responsible for more years of lost productive life than any other cause, as shown in Figure 2B.(16) This calculation takes into account the years remaining to age 65, so fatalities and disabilities involving young adults are weighted most heavily. Motor vehicle injuries account for the greatest fraction of years lost due to accident injury, and the total loss is equivalent to that from cancer.

The typical victim of a motor vehicle crash is multiply injured, and while musculo-skeletal injuries are most common (Table I), they are not the major contributors to fatality and disability. The head is the second leading site of injury, and is the body region most severely injured in half of the victims.(7, 9) The most frequent brain injury is short duration unconsciousness (<15 minutes); mounting clinical evidence suggests that even these generally recoverable injuries can result in permanent deficit in as many as 10% of the cases.(17) Longer duration unconsciousness and coma represent the more severe brain injuries, frequently associated with intracranial hemorrhage, skull fracture and local contusions of brain tissue.(18) Prompt emergency medical care and aggressive treatment can often prevent fatality in even severe brain injury, but functional recovery is frequently incomplete.(11, 15)

Spinal cord injury is a less frequent occurrence in motor vehicle accidents, but the high frequency of associated impairment makes it an important contributor to injury and disability.(13, 14) Continuing advances in our understanding of the physiologic response of brain and spinal cord tissue to injury are suggesting improvements in acute care, which may ultimately lead to more complete recovery.(2, 3, 5) In addition, improved knowledge of injury physiology, biomechanics and methods of evaluating injury risk could significantly advance safety engineering.(7)

Interpretation of available brain and spinal cord injury data is made difficult by the lack of information detailing the relative frequency of each injury severity for motor vehicle related CNS trauma, in particular for those sustained by automobile occupants. Data used in this and other papers reflect the overall distribution of brain and spinal cord injury severity. The data presently available do, however, allow national projections which provide a rough perspective of the distribution of traumatic brain and spinal cord injuries.

We present in this paper a unique combination of epidemiologic, hospital release and field accident data to obtain more meanginful estimates for the annual incidence of Central Nervous System (CNS) trauma and related fatality and disability. We also estimate the fraction of these injuries which are related to motor vehicle accidents. These data were developed to provide direction for our long-range planning of on-going CNS injury research and to provide data for allocation of resources to further our understanding of brain and spinal cord injury.

Traumatic Brain Injury:

In a recent series of studies on the incidence of traumatic brain injury and serious impairment, Kraus found a rate of 180/100,000 population for the United States, with males having a rate 2.2 times greater than females.(15) Thus, based on the most recent census-estimated U.S. population (236,158,000) the projected annual incidence of traumatic brain injury is 425,000 in the United States. Hospital release data shown in Figure 3 project 71,100 fatalities annually.(1, 11) This represents an overall mortality for head injury of almost 17%, with approximately 2/3 of the fatalities at the scene of injury and 1/3 after admission to hospital). The vast majority of survivors experience good recovery with no neurologic sequelae or only mild impairment upon release from the hospital.(11) About 4% of the patients have moderate or severe impairment, or remain in a vegetative state with a diagnosis of brain injury as classified by the Glasgow Outcome Scale. Overall, approximately 7% of all brain injured patients discharged had neurologic deficit or disability identified by a physician after the course of primary care. This translates to a national projection of 24,775 people annually with long-term neurologic sequelae after traumatic brain injury. Recent studies show that up to 33,000 or 10% of those classified as good recovery may experience psychological or cognitive deficits which can affect employment and life-style.(5, 17)

Transport accidents were the primary cause of traumatic brain injury in 48% of the cases, and as shown in Table II, the majority were occupants of a passenger car, truck or bus.(11, 15) The data suggest a United States incidence of fatal brain injury among vehicle occupants of 21,150, or 2/3 of the reported 1984 fatalities for vehicle occupants.(9) However, as indicated earlier, caution must be exercised in drawing conclusions regarding the relative contribution of head injury to motor vehicle fatalities. For example, one can project from Kraus' San Diego based data that 6,825 fatal head injuries occur to motorcyclists each year.(15) Data from the Fatal Accident Reporting System, on the other hand, shows that the total of fatal motorcycle accidents for 1984 was 4430.(8) This discrepancy reflects the inherent limitations of using a small, non-representative sample to make national projections. In this case, motorcyclists are probably over-represented in the San Diego database since the local climate and life-style encourages their use as a means of transportation. The limitations are less significant for automobiles as a transportation class.

Traumatic Spinal Cord Injury:

Focusing attention on traumatic spinal cord injuries resulting in death or permanent disability, Kraus (13, 14) calculated an annual United States incidence of 5.3/100,000 population, consistent with other recent hospital based studies.(1, 6, 22) Again, census data lead to a projected incidence of traumatic spinal cord injury of 12,500 in the United States. Hospital outcome data for this injured population (Figure 4) indicate an annual fatality rate of 47.5%, or 5,940 people nationally.(13, 22) Similar to brain injury fatality, 3/4 of the fatalities occurred at the scene of injury and 1/4 after admission to the hospital. Patients who are admitted to the hospital with a spinal cord injury have a higher risk of dying in hospital than those admitted with acute brain injuries (16% in-hospital deaths with spinal cord injury versus 6% with traumatic brain injury).

In contrast to acute brain injury, however, the vast majority of survivors experience impairment at the time of discharge.(1, 13, 14, 22) Twenty-two percent are quadriplegic or paraplegic (2.5% and 19.5% respectively), while 61% experience some degree of paresis (muscle weakness) ranging from moderate to severe and 16% some other deficit. Although 44% of those patients admitted to the hospital with initial neurologic deficit are released with less severe impairment, national data indicate that fewer than 1% of all admissions experience good recovery.(22) This results in a national estimate of 6,500 people each year who experience neurologic impairment following traumatic spinal cord injury.

In 58% of the cases, transport accidents were the primary cause of the spinal cord injury. Table III shows that a majority (64%) of the transport related injuries occurred to occupants of a passenger car (53%) or truck/bus (11%). (13, 14) Using this data and estimated U.S. population from census information, it is possible to project a national incidence of fatal spinal cord injury for vehicle occupants at 2,200 and survivable injury with impairment at 2,435. Since 22% of survivors experience paralysis, the expected national incidence of injuries to vehicle occupants resulting in complete paralysis is 530, consistent with the estimate of approximately 500 each year determined by Huelke based on data from the National Crash Severity Study.(12)

Total CNS Injuries:

Combining the projections for transport-related CNS injury into a single national estimate, approximately 211,250 hospital admissions occur annually for brain and spinal cord, resulting in 37,575 fatalities and 15,660 discharge impairments. The total number of discharge impairments may be increased by up to 15,800 minor brain injuries with permanent impairment who are currently included in the good recovery group. Since the primarily youthful injured have a long life-expectancy, disabling injury is emerging as a costly national health care issue. A recent study of severely disabled victims of traffic accidents indicates an average life-expectancy after injury of 36 years, with nearly a quarter of the victims living more than 50 years with permanent disability.(16) When incidence is compounded with this long-term survival, the current population of individuals with traumatic disabilities in the United States associated with motor vehicle related brain and spinal cord injury can be estimated at over 500,000.

Conclusions:

Brain and spinal cord injuries have clear risks of permanent disability or fatality. Further, recent analysis of injury occurrence in Great Britain indicates that brain and spinal cord injuries continue to be an important accident consequence, particularly for the driver, even with widespread safety-belt use.(19) Although hospital admission data indicate that brain injury is 34-times more frequent than spinal cord injury, when outcome is also considered, the incidence of permanent disability from spinal cord injury is approximately 25% that of brain injury disability. Even if all mild disability from brain injury is included, the incidence and severity of which are still poorly defined, disability from spinal cord injury is 11% as frequent as disability from brain injury. Since it is the long-term consequence of these injuries rather than the frequency of hospital admissions which is significant, research and safety engineering resources should be allocated to reflect the significant incidence of permanent disability from spinal cord injury.

Data reported here for long-term outcome are based on CNS traumatic injury from all causes; the precise ratio of disability from brain and spinal cord injury to occupants in motor vehicle crashes is still unknown. Additional research is needed to gather data which will adequately characterize the spectrum of CNS injury severities occurring in motor vehicle accidents. An analysis conducted by the National Highway Traffic Safety Administration which used lost productive years as a measure of long-term disability indicated that, for motor-vehicle crash injuries, brain and spinal cord injury may contribute about equally to long-term disability.(10) Additional epidemiologic research specifically focused on CNS injuries sustained by motor vehicle occupants is needed.

Permanent disability resulting from injury is a major public health issue. As improved knowledge of the mechanisms of brain and spinal cord injury become available, and as representative criteria are developed for injury tolerance of the population at risk, new methods of evaluating injury potential can be used in design and product evaluation. These goals for safety engineering must include a balance between biomechanics of injury to both the protective skeletal elements and the neural tissue and pathophysiology of functional injury to the brain and spinal cord. Only through an improved understanding of both the physics and physiology of injury can appropriate decisions be made for improved occupant protection leading to significant reductions in permanently disabling CNS injuries.

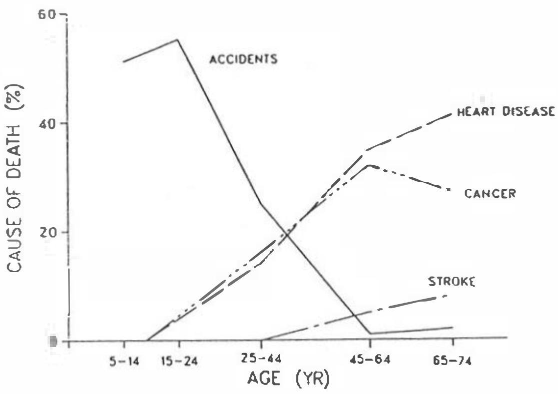

Figure 1: Percentage of U.S. fatality by cause and age.(4)

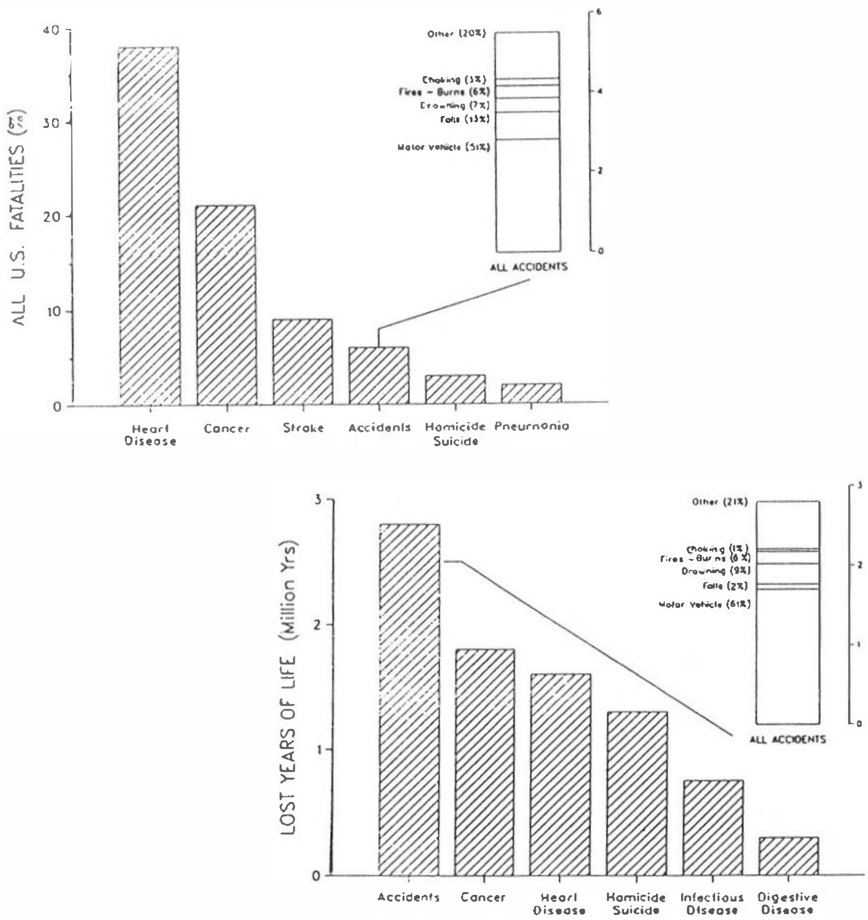

Figure 2: A) Leading causes of fatality in the United States.(4) B) Leading causes of lost years of productive life.(16)

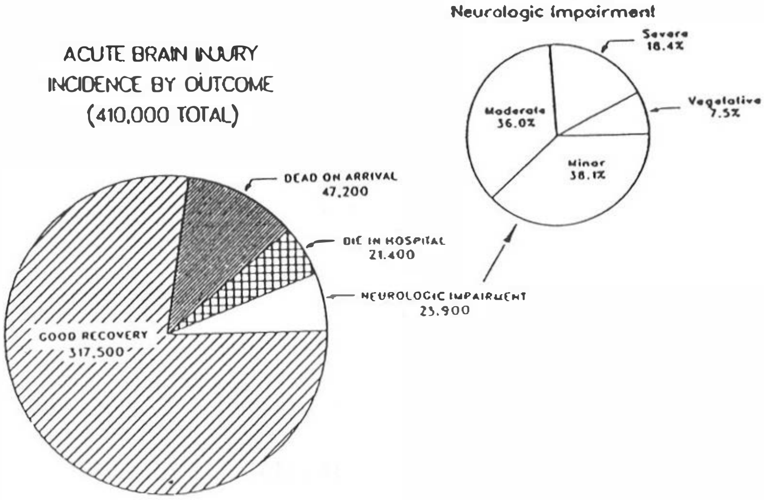

Figure 3: National projections for traumatic brain injury incidence, fatality and resulting disability.(1, 11, 15) Inset shows distribution of disabilities. The good recovery category may include up to 33,000 (10%) patients who exhibit psychological and cognitive deficits requiring special testing to document, but which may affect employment or life-style.(17)

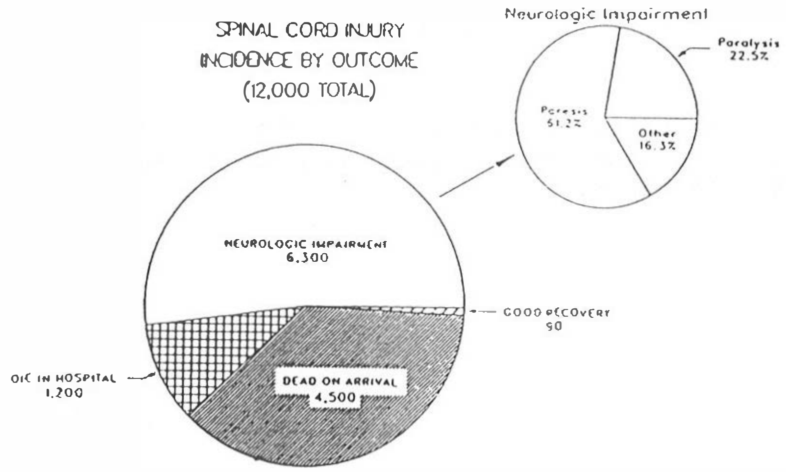

Figure 4: National projections for traumatic spinal cord injury incidence, fatality and resulting disability.(1, 6, 13, 14) Inset shows distribution of disabilities; 'other deficit' includes sensory loss and spasticity without specific diagnosis of paresis or paralysis.(22)

Table I

Distribution of Motor Vehicle Crash Injuries

Body Region	Injury Severity Level Minor AIS 1-2	Serious AIS 3-4	Critical AIS 5-6	Most Severe Injury *
Head**	2,613,000	50,000	17,000	50%
Spine**	929,000	13,900	2,000	16%
Chest	350,000	36,500	16,000	3%
Abdomen	257,600	55,400	12,000	5%
Extremities	3,245,000	105,000	---	26%
Whole Body	97,000	---	---	--
Total	7,491,000	260,000	49,000	100%

Data from 1983 NASS Summary.(9)

* Percent of individuals for whom this body region suffers the only or most severe injury.

**These categories represent anatomical injury to the head or spine, and include more than the less frequent neurologic injuries which are the subject of this paper.

Table II
Cause and Projected Incidence of Acute Brain Injury

	Incidence	Survive	Fatal
Car, Truck, Bus Occupants (62%)*	126,480	105,320	21,160
Motorcyclist (20%)	40,800	33,970	6,830
Pedestrian (12%)	24,480	20,390	4,090
Cyclist (6%)	12,240	10,190	2,050
All Transport (48%)	204,000	169,870	34,130
All Injury	425,000	353,900	71,100

*Percentages given represent percentage of transport-related incidence of brain injury.(15)

Table III
Cause and Projected Incidence of Acute Spinal Cord Injury*

	Incidence	Survive	Fatal
Car, Truck, Bus Occupants (64%)**	4,640	2,435	2,205
Motorcyclist (10%)	725	380	345
Pedestrian (17%)	1,230	650	580
Cyclist (7%)	505	260	245
(2% Unknown)	150	80	70
All Transport (58%)	7,250	3,805	3,445
All Injury	12,500	6,560	5,940

*Injuries to the spinal cord are generally coded as severity level 5 or 6 on the Abbreviated Injury Scale (AIS).

**Percentages given represent percentage of transport-related incidence of spinal cord injury.(13, 14)

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