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Causes and costs of spinal cord injury in the United States

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A cross-sectional multicenter study was conducted to estimate the direct costs for each cause of spinal cord injury in the United States. Random samples of 227 new injuries and 508 persons 2–16 years postinjury were selected. Prospective data were collected during one year on all charges for emergency medical services, hospitalizations, attendant care, equipment, supplies, medications, environmental modifications, physician and outpatient services, nursing homes, household assistance, vocational rehabilitation, and miscellaneous items. In 1995 dollars, first year charges averaged $233 947 for vehicle crashes, $217 868 for violence, $295 643 for sports, $185 019 for falls and $208 762 for other causes. Recurring annual charges for each cause averaged $33 439, $17 275, $27 488, $26 238 and $23 510, respectively. Using average age at time of injury for each cause, a 2% real discount rate, and the most recent survival data from the National Spinal Cord Injury Statistical Center, average lifetime charges for each cause were $969 659, $613 345, $950 973, $630 453 and $673 749, respectively. Given an estimated 10 000 new cases of spinal cord injury occurring each year of which 35.9% are caused by vehicle crashes, 29.5% are caused by violence, 20.3% are caused by falls, 7.3% are caused by sports, and 7% result from other causes, annual aggregate direct costs of traumatic spinal cord injury in the United States are $3.48 billion for vehicle crashes, $1.81 billion for violence, $1.28 billion for falls, $694 million for sports and $472 million for other causes. Total direct costs for all causes of SCI in the United States are $7.736 billion.

Keywords: spinal cord injury; causes; economics; epidemiology

Introduction

Each year, approximately 10 000 persons in the United States incur a spinal cord injury (SCI) requiring hospitalization.[1] The costs of these injuries to both individuals and society are staggering.[2,3] Moreover, with advancing medical technology and increasing life expectancies,[4–6] the costs of SCI are increasing at a rapid pace. Given a current political climate that demands cost containment and health care reform, it is essential to have rigorous estimates of the aggregate costs of SCI to society to ensure that adequate funds are allocated to prevention activities, appropriate research initiatives aimed at improving the quality of life for persons with SCI, and the medical management of these individuals for whom the government often serves as the responsible third-party payor. Therefore, the purpose of this study was to estimate the national aggregate direct costs of SCI in the United States from a public health perspective focused on the leading causes of these catastrophic injuries.

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Methods

A cross-sectional multicenter study was conducted to estimate the direct costs associated with each of the leading causes of SCI in the United States. For these purposes, direct costs were defined as charges incurred by either persons with SCI or their responsible third parties that were the direct result of the injury. Charges pertaining to medical conditions that were not directly related to SCI were not considered. No attempt was made to determine the amount of charges that were actually reimbursed, or the proportion of charges that constituted actual out-of-pocket expenses for the person with SCI.

Study population

The study population included a random sample of 508 persons originally treated at a federally designated model SCI system of care between 2 and 16 years previously and enrolled in the National Spinal Cord Injury Statistical Center (NSCISC) database. Eligibility criteria and characteristics of people who have been enrolled in the NSCISC database have been described previously.[1,7] Briefly, persons must have had an SCI caused by a traumatic event, must have been treated at a model SCI system within 60 days of injury, and must have had a clinically discernible degree of spinal cord neurologic impairment on admission to be enrolled in

the NSCISC database. Model SCI systems that participated in this study were located in Birmingham, AL, Atlanta GA, Fishersville VA, Philadelphia PA, New York NY, Boston MA, Chicago IL, Detroit MI, Ann Arbor MI, Englewood CO, Downey CA, and Houston TX.

Data collection

A 1 year cross-section of data was collected prospectively on all charges incurred during the year as a direct result of the injury. Initial data collection was by periodic telephone interviews and diaries kept by study subjects. In most instances, charges were verified by either the provider or the third-party payor. Charges included those for hospitalizations, attendant care, physician and outpatient services, equipment (purchase/lease/rental and repairs), supplies, medications, environmental modifications (home, work site, and vehicle), nursing home stays, household assistance, vocational rehabilitation, and miscellaneous items. In addition, 227 newly injured persons were randomly enrolled to assess, prospectively, the unique expenses for emergency medical services, acute care and rehabilitation that occur during the first year after injury.

Shadow pricing was used in instances when free items or services were provided so that their fair-market value could be estimated and included in the cost analysis. However, no attempt was made to adjust for needed items or services that were not received because of the limited resources of the study participant.

Information on the causes of SCI was already included in the NSCISC database. For this study, specific causes were grouped into five categories: motor vehicle crashes; acts of violence, sports, falls and all others. Motor vehicle crashes included cars, trucks, buses, motorcycles, boats, aircraft, snowmobiles, bicycles, all-terrain vehicles, trains, tractors, etc. Acts of violence were either intentional or unintentional, including gunshot wounds, stabbings, explosions and person-to-person contact. Falls and sports are self-explanatory, while all others included being hit by a falling/flying object, pedestrians, adverse effects of medical, surgical or diagnostic procedures and treatment for non-spinal cord conditions, machinery accidents, and other miscellaneous causes.

Statistical analysis

All charges were adjusted to 1995 dollars using the Medical Care Component of the Consumer Price Index. Means and standard errors of the mean for the total charges incurred during the year were calculated for each cause of SCI. Separate estimates were calculated for the first year after injury. Beyond the first year, no significant trends in average charges were observed over time. Therefore, annual charges after the first year were assumed to be constant, and a single average figure was calculated.

The present value of lifetime charges for an individual with SCI secondary to each cause was estimated using the mean first year and recurring annual charges for that cause, mean age at time of injury for all persons in the NSCISC database whose injury was due to that cause, 0%, 2% and 4% discount rates, and the most recent survival data from the NSCISC by using the following formula:

$$\text{PV Lifetime Charges} = \sum (DC_t)(PS_t)/(1+d)^{t-1}$$

where:

t = the number of years postinjury
DC_t = direct charges in postinjury year t
PS_t = probability of surviving to postinjury year t given survial to the year of injury
d = the discount rate

In this analysis, charges were assumed to be constant over time based on 1995 price levels. However, apart from changing price level, one dollar today is worth more than one dollar in the future because of the interest it could earn between now and then. The discount rate represents the difference between the rate of return on investments and inflation. For example, use of a 2% discount rate implies that the rate of return on investments will be 2% over and above inflation.

Methods used for estimating PS_t have been described in detail elsewhere.[4] Briefly, standard life table methods stratified by cause of injury were used to determine the number of deaths and the exact follow-up period for each person in the NSCISC database injured since 1973. Despite more than 20 years of follow-up, median (50%) survival for most causes of injury had not yet occurred. Therefore, the corresponding expected number of deaths was then determined by applying age-sex-race-specific general population annual mortality rates published by the United States government for the year 1985 (the midyear of the study period) to the actual follow-up period for each individual, and summing the result over all persons in the group. The actual number of deaths in each cause-specific group was then divided by the expected number of deaths for that group to produce standardized mortality ratios for each cause of SCI. The standardized mortality ratios were then used to revise 1990 United States government life tables (the most recent available when the calculations were made) to determine PS_t.

Aggregate annual direct costs attributable to each cause of SCI were then calculated by multiplying the cause-specific average present value of lifetime charges by the estimated number of new cases that result from each cause each year. Overall incidence of SCI was estimated based on previously published studies.[8–15] Taken together, these studies suggest the incidence of

SCI in the United States is about 10 000 new cases per year. The proportion of cases in the NSCISC database that result from each cause was then applied to the total incidence of 10 000 to estimate the number of new cases resulting from each cause each year.

Results

Of 2814 cases of SCI occurring between 1991 and 1995 that were reported to the NSCISC database, 35.9% were caused by motor vehicle crashes, 29.5% were caused by acts of violence, 20.3% were caused by falls, 7.3% were sports-related and 7.0% resulted from all other causes. This represents a significant shift in causes of SCI since the database was initiated in 1973. From 1973 to 1978, the distribution of causes of SCI reported to the NSCISC database was 46.3% motor vehicle crashes, 13.3% acts of violence, 16.8% falls, 14.6% sports and 9.0% for all other causes.

Average charges per case by cause of injury appear in Table 1. In 1995 dollars, average first year charges ranged from $295 643 for sports to $185 019 for falls. Average recurring annual charges for each cause ranged from $33 439 for motor vehicle crashes to $17 275 for acts of violence.

Average age at time of injury for each cause of SCI was 30 years for motor vehicle crashes, 27 years for acts of violence, 24 years for sports, 42 years for falls, and 38 years for all other causes. Estimated standardized mortality ratios were 3.79 for motor vehicle crashes, 4.04 for acts of violence, 4.23 for sports, 3.48 for falls and 3.00 for all other causes. Resulting average life expectancies given the average age at injury were 32.0 years for motor vehicle crashes, 33.8 years for acts of violence, 35.8 years for sports, 23.2 years for falls and 27.9 years for all other causes of SCI.

The estimated present value of average lifetime charges in constant 1995 dollars by cause of SCI appears in Table 2. Because the choice of an appropriate discount rate is never entirely clear, and because this selection has such a huge impact on the estimation of lifetime charges, results are provided using several different discount rates. Using a 2% discount rate, the average present value of lifetime direct charges attributable to SCI ranges from $969 659 for motor vehicle crashes to $613 345 for acts of violence (Table 2).

Table 1 Mean and standard error of charges per case by cause of injury (1995 $)

Cause of injury	*First year charges*	*Annual charges thereafter*
Motor vehicle crashes	233 947 ± 15 554	33 439 ± 3601
Acts of violence	217 868 ± 24 861	17 275 ± 2344
Falls	185 019 ± 19 327	26 238 ± 6020
Sports	295 643 ± 24 380	27 488 ± 4551
All other causes	208 762 ± 28 798	23 510 ± 5187

Applying the estimates of average present value of lifetime direct charges due to SCI that were based on a 2% discount rate to the estimated cause-specific incidence of SCI, total annual aggregate direct costs of traumatic SCI in the United States are estimated to be $3.48 billion for motor vehicle crashes, $1.81 billion for acts of violence, $1.28 billion for falls, $694 million for sports and $472 million for all other causes. Therefore, the present value of current and future direct costs that could be avoided if all new cases of SCI occurring this year in the United States could be prevented is $7.736 billion. The effect of altering the assumed discount rate on the estimate of annual aggregate direct costs for SCI by cause of injury appears in Table 3.

Public programs bear a considerable portion of the financial burdens of SCI (Table 4). Based on the most current NSCISC data, Medicare initially covers only 5.1% of persons with SCI; however, that figure rises to 31.3% by the fifth postinjury year as private insurance and other third-party support decreases. More than one-quarter of persons with SCI are covered by Medicaid, while one-tenth are covered by state vocational rehabilitation programs. Other public programs providing financial support for persons with SCI include the Veterans Administration, Public Health Service, and Crippled Childrens' Service. However, the data in Table 4 must be interpreted cautiously because sponsorship by the Veterans Administration and prepaid health plans such as health maintenance organizations is underrepresented in the NSCISC database. Persons with those sources

Table 2 Average present value of lifetime charges per case by cause of injury and assumed discount rate (1995 $)

	Discount rate		
Cause of injury	*0%*	*2%*	*4%*
Motor vehicle crashes	1 269 622	969 659	785 869
Acts of violence	783 736	613 345	511 102
Falls	765 029	630 453	539 219
Sports	1 249 682	950 973	775 766
All other causes	839 514	673 749	567 173

Table 3 Estimated total annual aggregate charges for SCI by cause of injury and assumed discount rate (billion 1995 $)

	Discount rate		
Cause of injury	*0%*	*2%*	*4%*
Motor vehicle crashes	4.56	3.48	2.82
Acts of violence	2.31	1.81	1.51
Falls	1.55	1.28	1.09
Sports	0.91	0.69	0.57
All other causes	0.59	0.47	0.40
Total	9.92	7.73	6.39

Table 4 Percentages of persons in the NSCISC database having each sponsor of care at initial hospital admission and 5 years postinjury (1973–1995)

Sponsor	*Initial admission**	*5 Years postinjury**
Private insurance	50.1	34.8
Medicaid	27.1	25.4
Vocational rehabilitation	11.7	8.5
Worker's compensation	10.7	8.9
Medicare	5.1	31.3
Champus or other insurance	3.2	2.1
Crippled children's service	2.6	0.5
Prepaid plans	2.1	1.0
Public health service	0.5	1.1
Veterans Administration	0.1	1.1

*Percentages do not sum to 100 because some persons have more than one sponsor

of support are usually treated at facilities that are not included in the model SCI system program.

Discussion

This analysis reveals considerable differences in charges attributable to each cause of SCI. Average initial and annual charges are high for sports mishaps because these events occur among younger persons and almost always result in tetraplegia.[1] Initial charges are lowest for falls because they often result in relatively incomplete neurologic injuries. However, annual charges rank third for falls because they typically occur among the elderly who are more likely to need attendent care and nursing home services. Motor vehicle crashes disproportionately result in tetraplegia (but not to the extent of sports-related SCI), and most often result in other simultaneous injuries (such as head injuries) that can increase both initial and annual charges because of their long-term consequences. Annual charges are lowest for SCI due to acts of violence because these events usually result in paraplegia rather than tetraplegia. However, initial charges rank third for acts of violence because of the increased frequency of concomitant internal injuries such as traumatic pneumothorax that require treatment but may not have long-term consequences.[1] Another possible explanation for the relatively low average annual charges incurred by victims of acts of violence is that they have more unmet needs than persons injured in other ways because they are less likely to have insurance or otherwise be able to pay for services.

Until now, the most recent study of aggregate direct costs of SCI in the United States was conducted by Berkowitz *et al*.[3] Adjusting their 1988 findings to 1995 dollars using the Medical Care Component of the Consumer Price Index, they estimated annual aggregate direct costs of SCI based on a 4% discount rate to be only $4.95 billion. Reasons that the estimate produced by Berkowitz *et al*. adjusted to 1995 dollars is lower than the current estimate of $6.39 billion at a comparable 4% discount rate are the exclusion of some costs such as those for emergency medical services, the conservative estimation techniques used for several other types of costs, the use of incidence statistics that were biased toward disproportionate inclusion of less costly neurologically incomplete injuries, and the use of life expectancy data from 1985 (the most current available at the time) that underestimate current life expectancies by a few years.

Costs associated with each specific cause of SCI were not differentiated by Berkowitz *et al*.[3] One study that did link costs to the cause of SCI was conducted by Smart and Sanders.[16] Their study only considered motor vehicle crashes. Adjusting their findings to 1995 dollars would result in estimated first year costs of $183 696 and annual costs of $30 063. The latter estimate is similar to that found in Table 1, however their estimate of first year costs is considerably lower than the current estimate of $233 947. At least part of the explanation for this difference results from the choice of inflation index used to adjust the findings of Smart and Sanders. Hospital and related services prices have risen faster than prices in the overall medical care sector. Since hospital charges are a major component of first year costs but not of annual recurring costs thereafter, use of the overall medical care component of the consumer price index will underadjust first year results of the study by Smart and Sanders and exaggerate the difference between the two studies.

The current estimate of annual aggregate direct costs of SCI is believed to be conservative for several reasons. First, acts of violence are thought to be slightly overrepresented in the NSCISC database.[1] Since acts of violence are the least costly etiology of SCI for individual cases, shifting the distribution of etiologies slightly toward other causes of injury would raise aggregate direct costs for all SCI. Conversely, a slight bias also exists in the NSCISC database toward overrepresentation of more severely injured persons that would have above average lifetime charges.[1]

Secondly, because of the trend toward increasing life expectancies that has occurred in recent years and the necessity to use survival data from persons injured some time ago, even the most current projections of life expectancy will somewhat underestimate the actual life expectancy of a newly injured person, and therefore underestimate lifetime costs. Thirdly, unmet needs of persons with SCI were not considered in the cost analysis.

Also, direct costs associated with persons who die before being admitted to the hospital were not considered. Although there may be as many as 5000 such cases each year,[17] the direct costs per case for these individuals will be negligible in comparison with those of persons who survive.

Some bias may have been introduced by the underrepresentation of persons who use Veterans

Administration services or are members of a health maintenance organization. Veterans comprise approximately 22% of the SCI population in the United States, but it is not known how many of those persons use Veterans Administration services rather than private sector services.[18] Interestingly, sponsor of care was not a statistically significant predictor of either initial or annual charges.[2] Moreover, costs identified in this study are only slightly higher than those reported by Berkowitz *et al*. whose sample included an overrepresentation of members of the Paralyzed Veterans of America.[3]

Indirect costs associated with lost wages, fringe benefits, productivity, leisure time, etc. also were not included in the current estimate of direct costs. Depending on age, injury level, educational level, and several other factors, indirect costs often exceed direct costs.[2,3] In fact, Berkowitz *et al*. estimated that only 35% of the total aggregate costs of SCI to society were direct costs, while 65% were indirect costs.[3]

An alternative method of assessing aggregate costs of SCI to society would be to combine estimates of the prevalence of SCI (number of persons with SCI who are alive today) with annual cost estimates. In contrast to the current estimate that represents the amount of money that could be saved if all new cases of SCI were prevented, the prevalence approach would represent the amount of money that could be saved if all existing cases of SCI were cured. Based on the original cost estimates of Berkowitz *et al*., the estimated 14% growth in prevalence of SCI in the United States since 1988 and adjusted to 1995 dollars, the direct cost savings for curing all existing cases of SCI in 1995 would be approximately $6.14 billion.[3,18]

Conclusions

Given the high costs and severe physical consequences of SCI, priority should be given to additional research aimed at developing and evaluating primary prevention programs for these injuries. Without considering the substantial value of lost productivity, a program that prevents a single SCI due to a motor vehicle crash will save money if it can be conducted for under $969 659. Moreover, most prevention programs that could be designed would not be specific for SCI. Other types of injuries that were prevented as a result of that program would generate additional savings.

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