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ORIGINAL RESEARCH

Improvements in Long-Term Survival After Spinal Cord Injury?

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Abstract

Objective: To investigate whether there have been improvements in long-term survival after spinal cord injury in recent decades.

Design: Survival analysis using time-varying covariates. The outcome variable was survival or mortality, and the explanatory variables were age, sex, level and grade of injury, and calendar year. The data were analyzed using the logistic regression model, Poisson regression model with comparison to the general population, and the computation of standardized mortality ratios for various groups.

Setting: National Spinal Cord Injury Model Systems facilities.

Participants: Persons (N=31,531) who survived 2 years postinjury, were older than 10 years, and who did not require ventilator support. These persons contributed 484,979 person-years of data, with 8536 deaths over the 1973 to 2012 study period.

Interventions: Not applicable.

Main Outcome Measures: Survival; survival relative to the general population; life expectancy.

Results: After adjustment for age, sex, race, etiology of injury, time since injury, and level and grade of injury, mortality in persons with spinal cord injury was higher in the 2005 to 2012 period than in 1990 to 2004 or 1980 to 1989, the odds ratios for these 3 periods were .857, .826, and .802 as compared with the 1970 to 1979 reference period.

Conclusions: There was no evidence of improvement. Long-term survival has not changed over the past 30 years.

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Trends in survival reflect underlying changes in lifestyle, health, and medical care. Life expectancy (the average survival time) is a particularly convenient summary measure because it reflects the mortality experience at all ages. It is an unambiguous measure of the vitality of a population and is often used for planning purposes.

Short-term survival after spinal cord injury (SCI) has improved markedly over the past 50 years. In particular, Strauss et al[1] reported that mortality during the first 2 years postinjury was 39% lower in the 1990 to 2004 period than in 1973 to 1979.

The same study reported a much lower reduction—14%, which was not statistically significant—in long-term survivors. In addition, the study found no trend toward improved survival over the 25-year period of 1980 to 2004. That is, life expectancy did not change for those who survived the first 2 years postinjury. Other authors have also found no trend.[2-9] The present work examines mortality in persons with SCI since 1973, focusing on the most recent period 2005 to 2012, to determine whether long-term survival has changed.

We also investigate how well the model from the Strauss et al[1] predicted mortality in the 2005 to 2012 period. That is, we determine the expected number of deaths using that model and compare it with the actual (observed) number of deaths. Any differences may suggest changes in the pattern of mortality in the interim.

Finally, we examine whether the standardized mortality ratio (SMR), that is, the ratio of the mortality rate in persons with SCI to the mortality rate in age- and sex-matched persons in the general population, has changed over time. This is of particular interest because to calculate life expectancy, some researchers

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have applied *previous* SMRs to *current* mortality rates in the general population to calculate mortality rates in persons with SCI required in a life table. It is not always recognized that this approach implicitly assumes that the SMR has remained constant over time. This assumption should be tested, and we do so here.

Methods

The study was approved by the Institutional Review Board of the University of Alabama at Birmingham. The data used here were an updated and expanded version of the U.S. national model systems database from Strauss et al.[1] Briefly, the entire (new) database included 49,241 persons with SCI who contributed 627,097 person-years of exposure and 12,799 deaths over the 1973 to 2012 study period.

Patients were identified and reported as deceased by data collectors at each model systems facility during their routine follow-up procedures. In addition, both the data collectors and the National Spinal Cord Injury Statistical Center (NSCISC) staff conduct periodic searches of the Social Security Death Index (SSDI) (available at www.ancestry.com) and other online databases including obituary files and records obtained from vital statistics departments in each state, for the 59% of patients with complete information. Patients with incomplete information, or those not verified as deceased, were censored at the last known date alive or the date the SSDI was last searched by the NSCISC staff. Data collectors at the centers are required to attempt to locate each patient every 5 years. As a result, few patients have been completely lost to follow-up (of 50,661 patients, only 77 were lost in the 1970s and 1668 in the 1980s). Most of these patients were censored during their first year postinjury and thus did not contribute to the present study. Limited searches of the National Death Index have also been conducted by the staff. The SSDI has been found to be 92.4% sensitive in identifying persons with SCI who are deceased.[10] Deaths most likely to be unreported in the SSDI occur in young persons, women, and unmarried persons.[11] Nonetheless, most, though probably not all, deaths not identified by the SSDI will be found by other follow-up procedures. Restriction to patients with social security numbers did not significantly affect the results of the present study. Specifically, the trends reported here (or lack thereof) were similar.

As in Strauss et al,[1] we performed survival analysis using time-dependent covariates.[12,13] In this analysis, the unit of analysis was not a person, as in many survival analyses, but was instead a person-year. With each person-year, an outcome variable indicating whether the person lived or died in that year was associated with possible explanatory variables such as age and severity of injury.

The analysis was restricted to person-years in which (1) the person was older than 10 years; (2) the level of neurologic injury was known; (3) the American Spinal Injury Association (ASIA) Impairment Scale grade was A, B, C, or D; (4) the person was not ventilator dependent; and (5) time since injury was ≥2.0 years.

The first restriction was imposed because long-term mortality effects of injury in childhood, when physiological development is incomplete, are different.[14] The fourth restriction was placed because ventilator dependence was the subject of a separate study.[15] Unlike the Strauss et al,[1] the focus here was solely on long-term mortality after SCI—hence the final restriction.

After all exclusions, a total of 31,531 persons, 8536 of whom died during the 39-year study period, contributed 484,979 person-years to the data set.

We used 3 primary methods to analyze the person-years data:

1. Modeling mortality rates in persons with SCI. Specifically, we used the logistic regression model[16] to relate the outcome variable (lived or died) to the set of possible explanatory variables.

   As in Strauss et al,[1] the explanatory variables used herein were age, sex, ethnicity, etiology of injury, level and grade of injury, time since injury, and calendar year. We fit the same model as in Strauss et al,[1] with the exception of an additional term for the most recent calendar year period. We also fit other models, as described below.
2. Comparison of the observed number of deaths in the 2005 to 2012 period with the number expected on the basis of the logistic regression model from Strauss et al.[1,17] There were 2 purposes of this comparison: (a) to determine whether the previous model developed using data from the 1973 to 2004 period adequately predicted mortality in the most recent period, and (b) to examine closely any changes in mortality in the earlier period (1973−2004) and that in the later period (2005−2012). Specifically, we used the model given in table 3 of Strauss et al,[1] which was developed using data from 1973 to 2004 for persons who survived ≥2 years postinjury and in particular calibrated to the 1990 to 2004 time period, to estimate the actual number of deaths in the most recent period (2005−2012). We stratified the results by various subgroups of interest.
3. Modeling trends in SMR. We used the Poisson regression model[18] to examine whether mortality in persons with SCI relative to the general population has changed over time.
   The outcome variable in the model was the ratio of the mortality rate in persons with SCI to the mortality rate in the age-, sex-, and calendar year−matched persons in the general population, which is the SMR. Explanatory variables were age, sex, race, etiology of injury, time since injury, and level and grade of injury. Mortality rates in the U.S. general population were obtained from the Human Mortality Database.[19] Our null hypothesis was that mortality in persons with SCI improved (ie, declined) at the same rate as that in the general population in the study period.

   We also calculated the empirical SMRs[20] for various groups: These are the observed number of deaths for a particular group divided by the number that would have been expected on the basis of the mortality rates of the corresponding age-, sex-, and calendar year−matched persons in the general population.[20]

As will be seen later, the above methods are complementary. We also provide brief descriptive statistics for the previous (1973−2004) and current (1973−2012) populations, as well as life expectancies calculated using the previous and current logistic regression models. Life expectancies were obtained from life tables, which were constructed in the standard way.[1,21]

List of abbreviations:

ASIA	**American Spinal Injury Association**
CI	**confidence interval**
NSCISC	**National Spinal Cord Injury Statistical Center**
OR	**odds ratio**
SCI	**spinal cord injury**
SMR	**standardized mortality ratio**
SSDI	**Social Security Death Index**