ORIGINAL ARTICLE

Behavioral Risk Factors of Mortality After Spinal Cord Injury

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ABSTRACT. Krause JS, Carter RE, Pickelsimer E. Behavioral risk factors of mortality after spinal cord injury. Arch Phys Med Rehabil 2009;90:95-101.

Objective: To test hypothesized relationships between multiple behavioral indicators and mortality among persons with spinal cord injury (SCI), while controlling for biographic and injury characteristics.

Design: Prospective cohort study with behavioral data collected by mailed survey in late 1997 and early 1998. Mortality status was ascertained as of December 31, 2005.

Setting: A large rehabilitation hospital in the southeastern United States.

Participants: Adults (N=1386) with traumatic SCI, at least 1 year postinjury.

Interventions: Not applicable.

Main Outcome Measures: Primary outcome was time from survey to mortality or censoring. Mortality status was determined using the National Death Index and the Social Security Death Index. There were 224 deaths (16.2%) in the full sample, and due to missing data, 188 deaths were observed in the 1251 participants included in the final statistical model.

Results: Cox proportional hazards modeling identified several significant behavioral predictors of mortality. In the first set of analyses, the significance of a single behavioral variable was assessed while controlling for biographic and injury predictors. We subsequently built a comprehensive model based on an optimal group of behaviors. The best set of behavioral predictors included: smoking, binge drinking (number of episodes with 5 or more drinks), prescription medication use, and number of hours out of bed per day. Inclusion of these variables improved prediction of survival compared with biographic and injury variables alone, as the pseudo-R^2 increased from .121 to .164 and the concordance from .730 to .769.

Conclusions: The results affirm the importance of avoiding basic risk behaviors, such as smoking and alcohol misuse, and affirm their importance as targets of intervention in association with SCI rehabilitation.

Key Words: Health behavior; Mortality; Rehabilitation; Risk; Spinal cord injuries.

DESPITE ADVANCES IN medicine over the past few decades, people with SCI are at high risk for early mortality.[1-3] There has been a trend for decreased mortality during the first year postinjury, which is the time during which medical advances may have the greatest effect, but long-term survival rates appear to have plateaued. Enhancing longevity is not solely dependent on advances in medicine but may also result from new knowledge from epidemiologic research that enhances prevention of secondary health conditions that lead to early mortality.

Nearly all studies of mortality have focused primarily on biographic and injury related variables as predictors of mortality. This is primarily due to convenience, because these factors are most readily available on large participant cohorts. Risk of mortality is actually higher in the first year after SCI onset.[4-6] The risk during the first year is greatest for those with the most severe injuries, particularly those who are ventilator dependent. However, life expectancy is enhanced through the first few years after onset for those with the most severe injuries.[7] Higher neurologic level and completeness of SCI, ventilator dependency, and older age at injury are related to an elevated risk of mortality.[6,8-13]

Causes of Death

DeVivo and Stover[14] classified a total of 1403 deaths recorded on death certificates into categories suggested by the National Center for Health Statistics. Pneumonia and influenza were the primary cause of death (17.7%), followed by nonischemic heart disease (16.5%), and septicemia (12%). They calculated cause-specific standardized mortality ratios to compare causes of deaths of persons with SCI with the number of deaths expected in the general population for each cause. The highest standardized mortality ratios, suggestive of those causes most problematic for people with SCI, included septicemia (64.2 times the general population), disease of the pulmonary circulation (47.1), pneumonia and influenza (35.6), symptoms and ill-defined conditions (13.8), and diseases of the urinary system (10.9). The causes of death that were least likely associated with SCI were homicide, legal intervention, and cancer.

Studies of causes of death after SCI report a sizable proportion of deaths due to preventable factors that appear related to a person's psychologic adjustment or behavior, including suicide.[14,15] The prevalence of these causes of death provides indirect evidence of the importance of prevention and control of the major psychologic and behavioral risk factors associated with premature mortality. Poor adaptation was found predictive of mortality up to 15 years after SCI. Krause et al[16] found that

List of Abbreviations

IQR	interquartile range
NDI	National Death Index
SCI	spinal cord injury

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persons who were unemployed had a 2.38 greater odds of being deceased 11 years later than persons who were employed. One SD on the dependency scale was associated with a 2.04 greater odds of mortality over the study period.

General Risk Model for Prediction of Mortality

Krause[17] developed a model to guide research identifying empirical links between different classes of variables with mortality. At the time of the model development, prediction of mortality was virtually restricted to relationships between biographic and injury characteristics and early mortality. A building block approach was used to develop the multi-stage model that includes 4 levels of predictive factors for mortality, including in descending order: (1) biographic and injury factors, (2) psychologic factors/environmental factors, (3) risk and protective behavioral factors, and (4) health and secondary conditions. According to the model, the strength of association with mortality is directly related to the proximity of predictive factors to mortality in the model, and each sequential stage of the model both predicts subsequent levels in the model and is predicted by the previous set of factors (the exception to both of these conditions is for the most basic component of the model—biographic and injury factors). Therefore, with regard to strength of association, health factors would be the strongest predictors of mortality, followed by behavioral factors, and then psychologic and environmental factors. Furthermore, health factors are the most immediate predictors of mortality[18] but are themselves predicted by risk and protective behaviors. Behaviors predict health outcomes and are themselves predicted by psychologic and environmental factors.

At least partially as a result of the development of the model, there has been an increase in research that has investigated nonbiographic and noninjury variables in relation to mortality. In one such study, data from the Model SCI Systems indicated that having a violent etiology of SCI onset, a behavioral factor with limited direct implications for prevention, was associated with a greater likelihood of mortality.[2] In a second study,[7] the general risk model was tested using data from Model SCI Systems, finding support for the importance of each type of factor in the model but only mixed evidence for the sequencing of factors. As predicted, health factors were the most immediate risk factors for mortality based on increases in the generalized R^2 and concordance rates, but the addition of income (a proxy for environmental factors such as access to resources) was associated with the greatest increase in life expectancy. Adding participation, economic resources, and general health indicators to the model substantially enhanced the prediction. For instance, the predicted life expectancy of a 25-year-old person with C6 complete tetraplegia increased from 33.1 years (64.8% of normal) to 41.2 years (80.6%) when assuming favorable outcomes on this cluster of factors (a substantial protective effect and the type of analysis central to the study). The data used in this study were not collected specifically for the purpose of either testing the model or predicting of mortality, so the set of predictors was very limited.

This study was directly replicated using updated data from Model SCI Systems. Strauss et al[19] found a less powerful effect of economic factors, because one of the primary indicators of economic status (workers compensation) was no longer significant after the addition of more cases and was dropped from the model. Because the focus in this replication was on the importance of economic factors, there was no explicit test of the model. In a study solely directed at economic factors,[20] after controlling for biologic, biographic, and injury variables, participants who reported household income of less than $25,000 per year had a 4.5 times greater odds of dying over a 6-year period than those whose household income was greater than $75,000 per year.

In the aforementioned prospective cohort study,[18] the predictive efficacy of secondary conditions and other health factors (the set of risk factors most proximal to mortality in the general risk model) were investigated in relation to mortality status. Two sets of Cox proportional hazards modeling analyses were conducted—the first identifying the significance of a single variable of interest (controlling for biographic and injury status) and the second analysis building a comprehensive model based on an optimal group of variables. Several types of health conditions were associated with mortality. The best set of health predictors included probable major depression, surgeries to repair pressure ulcers, fractures and/or amputations, symptoms of infections, and days hospitalized. Several predictive models were generated based on subsets of predictor variables. The model that included only the health factors alone was superior to a model that included injury severity alone, as indicated by the pseudo-R^2 (health factors=.075; injury severity=.016) and the concordance R^2 (health factors=.676; injury severity=.578). Comparison of these models shows the importance of health factors in comparison with injury severity in predicting mortality. When all biographic factors (including age) were added, the model that included all biographic and injury variables improved, because the pseudo-R^2 increased to .121 and the concordance R^2 to .730. However, a comprehensive model that included the secondary conditions and general health item was the best overall model, because the pseudo-R^2 increased from .121 to .178 and the concordance from .730 to .776. One particularly important aspect of this study is that the selection of variables for investigation was done prospectively, specifically with the intention of evaluating the general risk model. All other studies have investigated existing data in relation to mortality.

Taken together, the findings from these studies suggest that the general risk model is appropriate for guiding research as to risk of mortality. Some of the more important findings relate to the relationships between specific secondary conditions, such as pressure ulcers and depressive symptoms, with early mortality. Economic factors also are important, although these factors largely appear to be proxy variables for other nonspecified variables that may relate to issues such as access to quality care. From the perspective of the risk model, it is important to identify risk and protective behaviors in relation to mortality, because these have increasing implications for prevention.

Purpose

The purpose of this study is to identify the association of several sets of behavioral factors with mortality status controlling for biographic and injury characteristics that have typically been associated with mortality after SCI. A prospective cohort design was used with mortality status determined approximately 8 years after collection of data on predictor variables.

Hypotheses

Our hypotheses were (1) when statistically controlling for biographic and injury characteristics, health behaviors will be associated with hazard of mortality and (2) when building an optimal risk model for mortality, inclusion of behavioral factors will enhance our prediction of hazard for mortality above and beyond that of biographic and injury factors alone.