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Risk of mortality after spinal cord injury: Relationship with social support, education, and income

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Abstract

Study Design—Prospective cohort study.

Objective—To identify the association of social support and socioeconomic factors with risk of early mortality among persons with SCI.

Setting—Participants were identified from a large specialty hospital in the Southeastern United States.

Methods—Data was collected by mailed survey, and mortality status was ascertained approximately 8 years later. The 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 observed deaths (16.2%) in the full sample (n = 1,386). Due to missing data, the number of deaths used in the final analysis was 188 (out of 1249 participants).

Results—Cox proportional hazards modeling was used to build a comprehensive predictive model. After controlling for biographic and injury related factors, two of four environmental predictors were retained in the final model including low income and general social support. Years of education and the upsets scale, another aspect of social support, were not retained in the final model. Inclusion of these variables resulted in only modest improvement in the prediction of survival compared with biographic and injury variables alone, as the pseudo-R^2 increased from .121 to .134 and the concordance from .730 to .751.

Conclusion—Environmental factors are important predictors of mortality after SCI.

Keywords

Spinal cord injury; mortality; social support; education; income

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Introduction

While there has been a trend of decreased mortality during the first year after spinal cord injury (SCI),1 long-term survival rates appear to have reached a plateau. Risk of mortality is highest in the first year 2–4 and is greater for those who have higher neurological levels of injury, neurologically complete injuries, and those who are ventilator dependent.4–8 The risk of mortality among ventilator dependent individuals decreases substantially the longer the individual has survived.9

There has been an increased focus on non-biographic and non-injury risk and protective factors for SCI. Krause10 developed a multi-stage general risk model of mortality after SCI that includes four levels of predictive factors, including in descending order: (1) biographic and injury factors, (2) psychological factors/environmental factors, (3) risk and protective behavioral factors, and (4) health and secondary conditions. After accounting for biographic and injury factors, 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 predicts subsequent levels in the model and is predicted by the previous set of factors. Health and secondary condition variables most directly contribute to mortality and are themselves predicted by health behaviors, which are in turn predicted by psychological and environmental factors.[*]

There has been an increase in research that has investigated factors from the model in relation to mortality. In a prospective cohort study of health factors, the optimal set of health predictors included probable major depression, surgeries to repair pressure ulcers, fractures and/or amputations, symptoms of infections, and days hospitalized.11 When compared with a model that included only biographic and injury factors, the comprehensive model that included health predictors resulted in an increase of the pseudo-R^2 from .121 to .178 and the concordance from .730 to .776.

In another prospective study collected of 361 men with SCI, health risk factors for mortality including diabetes, heart disease, reduced pulmonary function, and smoking (a behavioral risk factor). The two most prominent underlying causes of death were diseases of the circulatory system (40%) and diseases of the respiratory system (24%). Findings from a retrospective study of hospital records of all cases admitted to a Norwegian hospital between 1961 and 2002 suggested that cardiovascular disease, substance abuse or alcohol abuse, and psychiatric disorders were contributory to mortality.7

In a report using data from the Model Spinal Cord Injury Systems (MSCIS) in the United States,9 at least one variable from each level in the model was found to be predictive of mortality. Health factors were associated with the largest increases in the generalized R^2. Concordance rates and the addition of environmental variables, including workers compensation, whether the person had a case manager, and sponsor of care, were associated with the greatest increase in life expectancy. This study was directly replicated using updated data from MSCIS, with a less powerful effect of economic factors, as one of the

[*]Psychological and environmental factors are fundamentally different variables but are on the same level in the model in terms of their relationship with other variables.

primary indicators of economic status (workers compensation) was no longer significant.[12] In another study that focused on economic factors, but not using MSCIS data, participants who reported household income of less than $25,000 per year had a 4.5 times greater odds of dying over a six-year period than those whose household income was greater than $75,000 per year.

The findings from these studies suggest that the general risk model is appropriate for guiding studies of risk of mortality, with some research suggesting importance of environmental factors, including insurance and income. Environmental factors are important to consider as they frequently represent proxy variables for the availability of services. Studies of social support are conspicuously absent in relation to mortality after SCI.

Purpose

The purpose of this study was to identify the association of four environmental parameters with mortality status, while controlling for biographic and injury characteristics. These characteristics include social support indicators (a general scale and another scale related to upsetting interactions) and two indicators of socioeconomic status (years of education and income). The results of the study shed further light on the importance of environmental factors within the general risk model.

Research Questions

1. When statistically controlling for biographic and injury characteristics, will the environmental factors of social support and socioeconomic status indicators be associated with the hazard of mortality?
2. When building an optimal risk model for mortality, will inclusion of social support and socioeconomic indicators substantially enhance the prediction of hazard for mortality above and beyond that of biographic and injury factors alone?

Materials & Methods

Prospective Data Collection Procedures

Institutional Review Board approval was obtained prior to initiating the study. Participants were identified from records of a large specialty hospital in the Southeastern United States. Participants were adults with traumatic SCI of at least one year duration. Questionnaires were sent to all participants 4–6 weeks after introductory letters. Two subsequent mailings were initiated for all non-respondents. Follow-up phone calls were also implemented, and additional materials were sent out when requested by the participant. Participants were offered a $20 stipend and were included in drawings totaling $1,500. Prospective data collection began July 1997 and ended April 1998.

Mortality status was determined approximately 8 years after obtaining the prospective data (December 31, 2005). The National Death Index (NDI) of the US National Center for Health Statistics and the Social Security Death Index (SSDI) of the US Social Security Administration were used to determine mortality status. NDI death records are available approximately 16 months after the conclusion of a given year, whereas the Social Security

Death Index is more current and may be done on a case-by-case basis through an online search. We did a one-time search of NDI records through the year 2005 and used the SSDI during the subsequent year to supplement this data.

Statement of Ethics

We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research.

Measures

A health survey was used to measure study variables. The portions relevant to the current study included measurement of biographic and injury characteristics, as well as the socioeconomic indicators of years of education and income. Income levels were presented in the same categories utilized in the Behavioral Risk Factor Surveillance System,13 a standardized instrument that is widely used by the Centers for Disease Control to monitor relevant basic health behaviors within the general population and in specific regions of the country. For the purpose of the analysis, an indicator variable for income was created to represent low income (income < $20,000) relative to income $20,000 or more.

The Reciprocal Social Support Scale14 was developed to measure support given and received. Individuals rated the frequency with which they receive four types of support: social interaction, material assistance, emotional support, and nonpaid personal assistance. Participants answer eight questions with a seven-point scale (1 = never; 7 = always) rating each type of support received from their families, friends, and community. They were also asked the frequency with which upsetting things happened between them and members of their family, their friends, or their community. Scores ranged from 3–21. Alpha coefficients for the current sample ranged from .70 to .76 for the four types of support, with an average of.73. The alpha for the upsets scale was.55, however low internal consistency is expected given that the scale sums evaluations made by three types of people: family, friends, and community. In the current study, we are using a total social support scale and the upsets score.

Analyses

A three stage hierarchical strategy to model building was employed to identify the association of each health variable with mortality and to define an optimal set of environmental predictors of mortality. Cox proportional hazards modeling was used with the number of days between the survey and event (i.e., mortality) as the dependent variable. The censoring date was December 31, 2005.

During the first stage of analysis, a base model consisting of biographic and injury characteristics, including functional injury classification, gender, race (Caucasian-Minority), age at time of injury, and years lived since injury to the time of survey, were specified.

The second stage of the analysis focused on adding single environmental variables to the model as a means of screening each of these potential predictors for inclusion in the final stage model. All variables significant at the alpha=0.10 level of significance were considered for subsequent modeling.15 Multicollinearity was assessed for all candidate variables that met the initial screening criterion ($p \leq .10$).

The final stage of the analysis formulated a Cox proportional hazards model that consisted of the base model in addition to the variables identified in stage two of the analysis. Backwards elimination was used to identify the final fitted model. The proportional hazards assumption of the final model was assessed using the Schoenfeld residuals16 and found to be tenable. The fit of the model was assessed using the likelihood ratio test and the C-statistic.17 The likelihood ratio test was used to calculate Nagelkerke's pseudo-R^2.[18] The value of the C-statistic is closely related to the area under a Receiver Operating Characteristic (ROC) curve and is interpretable as the probability that the cases (i.e., deaths) have higher risks as measured by the linear component of the regression model. Accordingly, a value of 0.5 is for chance prediction, and the discrimination of the model is improved as the C-value approaches 1.0. The interaction of income and social support was included in a new model to further assess goodness of fit. The Wald test indicated this interaction term was not needed in the model ($p = 0.85$), and, accordingly, the interaction term was removed. All model building was conducted using the SAS System version 9.1.3. The validation of the proportional hazards assumption and the estimation of the C-statistic were performed using STATA version 9.2.

Results

Participant Characteristics

A total of 1,386 participants returned usable materials (72% response rate). Of these, 1312 provided complete biographic and injury data and served as the base, or reference, sample for statistical analyses. The final statistical model, after eliminating those missing environmental items, consisted of 1249 participants, 188 (15%) of which were events.

In the subset of data that consisted of complete biographic and injury data (n=1312), 74% were male, and 76% were Caucasian (the majority of non-Caucasians were African-American). Average age at time of injury was 31.4 years, with a mean age of 40.3 years (interquartile range: 30.1 to 48.4) at data collection. The primary etiology was vehicular crashes (51%), followed by falls/flying objects (17%), acts of violence (13%), sports (12%), and other (7%).

Functional injury classification was defined according to a combination of injury level and neurologic completeness of injury that yielded five categories that were similar, but not equivalent, to those frequently reported in the SCI mortality literature.[*] Thirteen percent had upper cervical injuries (C1–C4) and were non-functional; 31% had a lower cervical injury (C5–C8) and were non-functional; 35% were non-functional with non-cervical injuries; 11% had a cervical injury but were ambulatory; and the remaining 10% had non-cervical injuries and were ambulatory.

[*]Convention has been to use four groups based on the breakdown according to the three levels for ASIA grades AC, with a single group denoting ASIA-D regardless of injury level. We have used ambulatory status in lieu of ASIA grades which are not available.

Modeling

Table 1 summarizes the results of statistical modeling. It includes an analysis of the relationship of the biographic and injury related factors with mortality, followed by consideration of the environmental parameters evaluated after controlling for the biographic and injury characteristics. The final model is summarized evaluating all biographic, injury related, and environmental parameters simultaneously.

Significant hazard ratios were observed for age at injury onset (HR=1.06, CI: 1.05, 1.07), years lived since injury (HR=1.05, CI: 1.03, 1.08), and injury severity. The two ambulatory groups were not significantly different from each other, although the 3 other injury severity groups were significantly different from the non-cervical/ambulatory base group. Participants with the most severe injuries (C1–C4, non-functional) had the greatest hazard (4.87). The two other groups with non-functional injuries (C5–C8 and non-cervical) also had significantly elevated hazard ratios but were actually modestly reversed from what would be expected (C5–C8 = 2.95, non-cervical = 3.19). Neither race nor gender was significant, but these were retained in the statistical model to account for their potential confounding effects.

Three of the four candidate predictors achieved the screening criterion for inclusion in the model building steps of the analysis (the social upsets scale did not reach the 0.10 level of significance). The final model yielded two of the four environmental indicators: low income (HR = 1.83, CI: 1.34, 2.51) and social support (HR =.96; CI =.93,.99). The mean (SD) of social support was 17.5 (3.9). Thus, a standardized hazard ratio of 0.86 was obtained. This value may be interpreted as the hazard of mortality decreases by 14% for every 3.9 unit increase in social support.

Table 2 compares the pseudo-R^2 and the C-statistic for the: (a) base model that includes all biographic and injury variables, and (b) the final model which includes the biographic and injury predictors along with social support and income. The pseudo-R^2 increased from .121 to .134 between the base model and the final model, and the C-statistic increased more modestly from .730 to .751.

Discussion

The unique contribution of this study is the identification of the association of social support and income as predictors of mortality after SCI. However, the extent to which these factors added to the prediction above and beyond a base model was limited, as the incremental increases in both the pseudo R^2 and the C-statistic were small and less than that associated with health factors.11 It is not surprising that the overall strength of the relationship of environmental factors is less than that of health factors, as this is consistent with the model and the more proximal role of health factors with mortality. However, it is also important to point out that only a limited set of environmental factors were investigated, so any direct comparisons between studies are tenuous.

Study Limitations

First, all data were self-report. Second, the data were heavily left censored, and there may be systematic differences between those who lived to participate and potential participants who died prior to initiation of the data collection. Third, we cannot assume causality from the design. This is an issue of interpretation and not prediction. Fourth, because the data were collected approximately eight years before determination of mortality status, the power of the study is limited as environmental factors could change during that interval. Lastly, measurement of environmental factors was restricted to social support and socioeconomic indicators.

Future Research

Because the current study was restricted to a limited number of environmental parameters, future research should address a wider array of predictors and include factors such as access to health care, access to physicians, adequacy of personal assistance services, and proximity to health care. Each of these factors is to some degree related to socioeconomic status. Intervention studies are needed that identify individuals at the highest risk for early mortality and address those factors that place them at risk. Diligence in continuing this line of research and closely attending to the policy implications of the findings are necessary to improve the overall health and longevity of people with SCI.

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Table 1

Model fit summary

	Unadjusted Model		Adjusted Model[1]		Final Model				
Variable	**HR**	**p-value**	**HR**	**p-value**	**HR[2]**	**95% CI**		**p-value**	**Std HR[3]**
Injury Classification									
C1–C4, non-functional	1.64	0.01		NA	4.87	2.32	10.20	<0.0001	
C5–C8, non-functional	0.97	0.85		NA	2.95	1.45	6.00	0.00	
Non-cervical, non-functional	1.19	0.23		NA	3.19	1.58	6.44	0.00	
Cervical, ambulatory	0.63	0.08		NA	1.14	0.48	2.71	0.77	
Non-cervical, ambulatory (referrent)	1.00	--			1.00	--	--	--	
Biographic									
White	0.84	0.25		NA	1.12	0.80	1.57	0.52	
Male sex	1.06	0.72		NA	1.20	0.85	1.69	0.31	
Age at injury	1.05	<0.0001		NA	1.06	1.05	1.07	<0.0001	2.29
Years since injury	1.02	0.06		NA	1.05	1.03	1.08	<0.0001	1.59
Environmental variables									
Years of education Low income	0.93	<0.01	0.96	0.08	--				
(Income<$20,000)	1.76	<0.0001	1.93	<0.0001	1.83	1.34	2.51	0.00	
Social support	0.96	0.01	0.95	<0.01	0.96	0.93	0.99	0.01	0.86
Social upsets	0.99	0.68	1.02	0.22	--				

[1] Estimated HR for environmental variables separately adjusted for injury and biographic variables only

[2] Hazard ratios are adjusted for all variables that have estimates provided. Years of education and social upsets were not included in the final model.

[3] The standardized HR are reported for 1 Std change in continuous variables

Table 2

Model fit statistics

Model	Pseudo R-squared	C-statistics
Base model[1]	0.121	0.730
Final model[2]	0.134	0.751

[1]The base model includes only the injury and biographic data.

[2]The final model as identified on Table 1.