ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2015;96:1000-5

ORIGINAL RESEARCH

Long-Term Survival After Traumatic Brain Injury Part II: Life Expectancy

Jordan C. Brooks, PhD, MPH,[a] Robert M. Shavelle, PhD,[a] David J. Strauss, PhD,[a] Flora M. Hammond, MD,[b] Cynthia L. Harrison-Felix, PhD[c,d]

From the [a]Life Expectancy Project, San Francisco, CA; [b]Department of Physical Medicine and Rehabilitation, Indiana University School of Medicine, Indianapolis, IN; [c]Craig Hospital, Englewood, CO; and [d]Department of Physical Medicine and Rehabilitation, University of Colorado, Denver, CO.

Abstract

Objectives: To compute the life expectancy of persons with traumatic brain injury (TBI) based on validated prognostic models from 2 cohorts, to compare mortality and life expectancy of persons with TBI with those of the U.S. general population, and to investigate trends toward improved survival over the last 2 decades.

Design: Survival analysis.

Setting: Postdischarge from rehabilitation units and long-term follow-up at regional centers.

Participants: Two cohorts of long-term survivors of TBI (N = 12,481): the Traumatic Brain Injury Model Systems (TBIMS) cohort comprised 7365 persons who were admitted to a TBIMS facility with moderate to severe TBI and were assessed at ≥1 years postinjury, and the California Department of Developmental Services (CDDS) cohort comprised 5116 persons who sustained a TBI and received long-term services from the CDDS.

Interventions: Not applicable.

Main Outcome Measures: Life expectancy.

Results: The estimates of age-, sex-, and disability-specific life expectancy of persons with TBI derived from the CDDS and TBIMS were similar. The estimates of age- and sex-specific life expectancy were lower than those of the U.S. general population. Mortality rates of persons with TBI were higher than those of the U.S. general population. Mortality rates did not improve and the standardized mortality ratio increased over the study period from 1988 to 2010.

Conclusions: Life expectancy of persons with TBI is lower than that of the general population and depends on age, sex, and severity of disability. When compared, the survival outcomes in the TBIMS and CDDS cohorts are remarkably similar. Because there have been no marked trends in the last 20 years, the life expectancies presented in this article may remain valid in the future.

Archives of Physical Medicine and Rehabilitation 2015;96:1000-5

Life expectancy is defined as the mean survival time in a group of similar people. It is normally derived from an actuarial life table that is based on a set of age-specific mortality rates or survival probabilities. Hence, life expectancy is often taken to be a summary measure of population health. For individuals, particularly those with disabilities who require lifelong care, life expectancy is a convenient summary of age-specific survival probabilities and plays a central role in medical and financial planning.

Persons with moderate to severe traumatic brain injury (TBI) do not live as long, on average, as uninjured persons in the general population.[1-16] Through examination of the National Institute on Disability and Rehabilitation Research—funded Traumatic Brain Injury Model Systems (TBIMS) national database, Harrison-Felix et al[3] found that the life expectancy of persons with moderate to severe TBI was reduced by 3 to 11 years, depending on age, sex, and race. This range increases dramatically when severity of long-term disabilities are also considered. For example, in a study of persons with TBI who were clients of the California Department

Presented to the International Brain Injury Association, March 22, 2014, San Francisco, CA.

Supported by the National Institute on Disability and Rehabilitation Research (NIDRR) of the U.S. Department of Education. However, the contents do not necessarily reflect the opinions or views of the Traumatic Brain Injury Model Systems Centers, NIDRR, or the U.S. Department of Education.

Disclosure: none.

0003-9993/15/$36 - see front matter © 2015 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2015.02.002

of Developmental Services (CDDS), Shavelle et al[7] found that the life expectancy of 10-year-old girls with TBI who did not walk and were fed by others was 43 years lower than that of the age- and sex-matched general population. The same study indicated that the reduction in life expectancy of 50-year-old men with TBI who walked well was only 4 years.

In this article, we work with an updated and extended version of the CDDS database studied by Shavelle[7] together with the TBIMS national database to derive new estimates of life expectancy according to age, sex, and disabilities in walking and feeding. We compare mortality rates of persons with TBI with those of age- and sex-matched persons in the U.S. general population and examine whether there have been trends toward improved survival over the last 20 years.

Methods

This study was approved by the Hospital Corporation of America-HealthONE Institutional Review Board at the TBIMS National Data and Statistical Center, Craig Hospital, Englewood, CO.

Cohorts and comparison groups

The TBIMS and CDDS study cohorts are described in supplemental appendix S1 (available online only at http://www.archives-pmr.org/). In brief, the TBIMS cohort included persons who sustained a TBI at the age of ≥16, who received comprehensive acute and rehabilitation care at a TBIMS center,[17] and who provided follow-up information on functional skills. The CDDS cohort included persons with TBI who received services from the CDDS. In each cohort, persons were classified into 4 comparison groups on the basis of their walking and feeding skills: (1) does not walk, fed by others; (2) does not walk, self-feeds; (3) some walking with a handheld device or unsteadily alone; and (4) walks well alone. These skills were assessed with the FIM instrument[18] in the TBIMS cohort and with the Client Development Evaluation Report (CDER)[19-22] in the CDDS cohort. The precise levels for each measure were given in our companion article.[23]

Statistical analysis

To estimate life expectancy, we constructed standard actuarial life tables that used age-, sex-, and disability-specific mortality rates as inputs. The mortality rates were taken to be the maximum of (1) the Poisson regression estimates from our companion article[23] and (2) the age- and sex-specific mortality rates of the U.S. general population. That is, we assumed that the mortality rates of the TBI cohorts would not be lower than those of the general population.

We then compared mortality rates of persons with TBI with those of the age-, sex-, and calendar year–matched U.S. general population by using the standardized mortality ratio (SMR). The SMR is calculated as the ratio of the observed number of deaths in a particular group to the expected number of deaths if the group had experienced the mortality rates of the general population. We used the mortality rates of the U.S. general population from the Human Mortality Database.[24]

To examine secular trends in mortality rates, we refit the Poisson regression models from our companion article to test whether mortality rates changed over the study period from 1988 to 2010. A similar extended Poisson regression analysis was used to test for trends in the SMR. In the this SMR regression analysis the natural log of the expected number of deaths in the U.S. general population was used as an offset (ie, a covariate whose coefficient was set to 1) on the right-hand side of the regression equation.[25]

Data were analyzed with SAS version 9.2[a] and R version 3.0[b] software.

List of abbreviations:

CDDS	California Department of Developmental Services
CDER	Client Development Evaluation Report
CI	confidence interval
SCI	spinal cord injury
SMR	standardized mortality ratio
SSDI	Social Security Death Index
TBI	traumatic brain injury
TBIMS	Traumatic Brain Injury Model Systems

Results

Life expectancy was closely related to the severity of disability as characterized by walking and feeding skills (table 1). Persons with the most severe disabilities had the shortest life expectancy, whereas those most mildly affected had the longest life expectancy. Ambulatory women lived longer, on average, than did ambulatory men. Among persons who did not walk, those who could feed themselves lived longer, on average, than those who could not. There were no significant sex differences among nonambulatory persons.

The life expectancy estimates derived from the CDDS and TBIMS were remarkably similar (see table 1). For example, the life expectancy of 20-year-olds who did not walk and were fed by others was estimated to be 24 and 25 additional years (ie, up to ages 44 or 45y) from CDDS and TBIMS, respectively. On average, 20-year-old men with TBI who walked well lived 9 to 10 years less than those in the general population. For 20-year-old women who walked well, the reduction in life expectancy was 7 to 8 years. Many of the pairwise comparisons of the CDDS and TBIMS life expectancies were identical when rounded to the nearest year. The largest differences were observed for middle-aged adults with the most severe disabilities. For example, the TBIMS life expectancies of 40- to 50-year-olds who did not walk and were fed by others were about 3 years lower than the CDDS life expectancies. The SEs of life expectancy estimates were typically 1 to 2 years, though they were somewhat larger for persons with more severe disabilities.

As in the general population, older persons with TBI had shorter life expectancies than did younger persons. For persons with TBI aged ≤60 years, life expectancy (even of persons who walked well) was lower than the age- and sex-specific life expectancy of persons in the U.S. general population. At the age of ≥70, however, the mortality rates of persons with TBI who walked well were not different from those of typical men and women in the U.S. general population. That is, a person aged ≥70 years who has a TBI and walks well will have an essentially normal life expectancy. Those with more severe disabilities had a shorter life expectancy even at advanced ages.

Our analyses of SMRs (table 2) complement the above-mentioned comparisons of TBI life expectancies with those of men and women in the general population. The overall SMRs for the TBIMS and CDDS cohorts were 2.4 (95% confidence interval [CI], 2.2–2.6) and 3.9 (95% CI, 3.6–4.2), respectively. The latter was higher because the CDDS cohort comprised younger persons with more severe disabilities. When the 2 cohorts were matched for age and severity of disability, the SMRs were similar. In persons aged 17 to 39 years who walked well, for example, the SMRs for CDDS and TBIMS cohorts were 2.8 (95% CI, 2.2–3.5) and 3.1 (95% CI, 2.3–4.0), respectively. For nonambulatory adults aged 40 to 59 years who did not feed