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ORIGINAL ARTICLE

Comparative Mortality of Adults With Traumatic Brain Injury in California, 1988–97

Robert Shavelle, PhD, MBA; David Strauss, PhD, FASA

We studied mortality rates of people with traumatic brain injury using the extensive California Department of Developmental Services database. The data provide mortality rates by age, gender, severity, cause, and associated conditions on 2629 subjects older than 15 years during 1988–97. Increased mortality was observed, particularly among patients with diminished mobility.

Address: Department of Statistics, University of California, Riverside, CA 92521-0138.

Correspondent: Robert Shavelle, PhD, MBA.

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Traumatic brain injuries account for over 1 million hospitalizations per year[1] and 50,000 deaths.[2] It is the leading cause of death among people younger than 35 years.[3] Our aim was to relate the increase in mortality to the severity of the disability, which has not previously been documented. Our interest was in long-term mortality risk, so we only considered data after the first post-injury year.

SUBJECTS STUDIED

The database (compiled and managed by the California Department of Developmental Services) comprises annual Client Development Evaluation Reports[4] (CDERs) on more than 200,000 people with developmental disabilities. These reports are prepared by regional centers throughout the state and include information upon entry and changes in medical, social, and living conditions. The reliability of CDER items has been assessed previously and judged satisfactory.[5–8]

Traumatic brain injury was determined by the *International Classification of Diseases, Ninth Revision* (*ICD-9*)[9] and/or indication that the person was involved in a motor vehicle accident and suffered mental impairment. The *ICD-9* codes were the same as those in previous studies,[10,11] namely 800–804 (fracture of skull) and 850–854 (intercranial injury).

We identified 2629 people over the age of 15 who had suffered a traumatic brain injury during the 1988–97 observation period. Demographic and other characteristics are summarized in Table 1 (the figures given are percentages). As may be seen, the majority of the subjects in this study were in the 15–29 years or the 30–44 years age groups. As is typical

Table 1. Demographic and Disability Characteristics of 2629 Adults With a Traumatic Brain Injury in the 1988–97 Registry of the California Department of Developmental Services

Category	Distribution (%)
Sex	
Male	67
Female	33
Ethnicity	
White	57
Hispanic	20
Black	12
Asian	4
Other	7
Age at first evaluation	
15–29	62
30–44	27
45–59	9
60+	2
Ambulation	
Does not walk	15
Intermediate levels*	19
Walks well alone at least 20 ft	66
Receptive language†	
Does not understand speech	27
Understands simple words	17
Understands simple phrases	18
Understands simple conversation	24
Understands complex conversation	14
Use of feeding tube†	
Yes	25
No	75

* Walks with support, or walks unsteadily alone at least 10 feet.

† The frequencies here are only for persons who cannot walk. Most persons who had some walking ability could understand simple conversation or better, and very few were tube fed.

in studies of traumatically injured patients, males predominated over females[10,12,13] by about a 2:1 ratio.

It is well known that mortality rates for patients with reduced mobility are increased.[10,14,15] We therefore stratified into 3 groups on the basis of ambulation. More than one third of the subjects had lost the ability to walk 20 feet. Table 1 also shows that a substantial proportion of the nonambulatory subjects suffered from serious cognitive deficits and/or required gastrostomy feeding.

The California database only includes people with developmental disabilities or relatively long-term cognitive deficits. For this reason, our sample is more heavily weighted to the more severely disabled patients than most published studies.

FOLLOW-UP

The CDER database was matched to annual California mortality data published by the California Department of Health Services, Bureau of Vital Statistics. Each person's exposure period started either with the first CDER evaluation or at 12 months after the date of injury, whichever came later. We thus excluded the first year after injury, when the mortality rate is particularly high. The end of the exposure period was taken as the date of death, the end of the study period (December 31, 1997), or 3 years from the last CDER, whichever came first. This last condition was

Table 2. Long-term Comparative Mortality (First Year Excluded) of Persons Disabled by Traumatic Brain Injury, Who Cannot Walk

Attained Age (y)	Exposure Patient Years (E)	Number of Deaths: Observed (d)	Number of Deaths: Expected (d')	Mortality Ratio (%) (100 d/d')	Mean Annual Mortality Rate Per 1000: Observed (q)	Mean Annual Mortality Rate Per 1000: Expected (q')	Mean Annual Mortality Rate Per 1000: Excess ($q - q'$)
15–29	1560	29	1.75	1655	18.6	1.1	17.5
30–44	936	15	2.06	727	16.0	2.2	13.8
45–59	370	12	2.11	570	32.4	5.7	26.7
60+	107	6	3.47	173	56.0	32.4	23.6
All	2973	62	9.40	660	20.9	3.2	17.7

* Basis of expected deaths: 1992 US Life Table rates for males and females.

Table 3. Long-term Comparative Mortality (First Year Excluded) of Persons Disabled by Traumatic Brain Injury, Who Can Walk With Support, Or Who Can Walk Unsteadily Alone At Least 10 Feet

Attained Age (y)	Exposure Patient Years (E)	Number of Deaths		Mortality Ratio (%) 100 d/d'	Mean Annual Mortality Rate Per 1000		
		Observed (d)	Expected (d')		Observed (q)	Expected (q')	Excess ($q - q'$)
15–29	1692	5	2.03	247	3.0	1.2	1.8
30–44	1096	5	2.52	198	4.6	2.3	2.3
45–59	394	6	2.23	269	15.2	5.7	9.6
60+	146	5	3.91	128	34.2	26.8	7.4
All	3328	21	10.70	196	6.3	3.2	3.1

* Basis of expected deaths: 1992 US Life Table rates for males and females.

Table 4. Long-term Comparative Mortality (First Year Excluded) of Persons Disabled by Traumatic Brain Injury, Who Can Walk Well Alone at Least 20 Feet

Attained Age (y)	Exposure Patient Years (E)	Number of Deaths		Mortality Ratio (%) (100 d/d')	Mean Annual Mortality Rate Per 1000		
		Observed (d)	Expected (d')		Observed (q)	Expected (q')	Excess ($q - q'$)
15–29	5409	18	6.77	266	3.3	1.3	2.1
30–44	3547	11	7.99	138	3.1	2.3	0.8
45–59	1172	11	6.69	164	9.4	5.7	3.7
60+	323	11	6.82	161	34.0	21.1	12.9
All	10,450	51	28.27	180	4.9	2.7	2.2

* Basis of expected deaths: 1992 US Life Table rates for males and females.

included to avoid the possible bias introduced by people who could have moved from the state and thus would have a hiatus in their CDER evaluations. Deaths were counted only if they occurred within the exposure period. The total exposure time was allocated to the appropriate sex and age intervals. The method yielded a total of 16,751 person years and 134 deaths.

RESULTS

The 1992 US Abridged Life Table[16] was used to derive the expected mortality rates (q'), as shown in Tables 2 through 4. The expected number of deaths was computed separately by sex and then summed over sex and the appropriate quinquennial age categories.

Overall mortality was substantially higher than for the California general population (mortality ratio [MR] = 277%). The data in Tables 2 through 4 indicate that mortality rates were particularly elevated in the nonambulatory group (MR = 660%), compared to those in the group with partial ambulation (MR = 196%) and those in the ambulatory group (MR = 180%). As has been found previously for other chronic disabilities,[17] the MR tends to decrease with age and the excess death rate tends to increase with age.

DISCUSSION

The population considered here appears to be the largest group with traumatic brain injury to be studied with respect to long-term risk-adjusted mortality. As we have seen, there is an increase in mortality rates particularly among the nonambulatory patients. The increase among the more ambulatory pa-

tients is more modest and proves comparable to the findings of earlier studies from Germany[18] and the United Kingdom.[12,13]

Concerning the causes of excess mortality, Roberts[12] and Lewin et al[13] found elevated death rates due to the following causes: pneumococcal meningitis, epilepsy, suicides, accidents (notably drowning), and respiratory disease. We hope to report shortly on the corresponding findings in our own population.

The results of Tables 2 through 4 can be used to construct life tables, and thus life expectancies or median survival times. To extrapolate mortality rates over the entire life span, one may use a model by which the logarithm of the MR declines linearly, with parity reached at age 100. For further explanation and empirical justification, see Strauss and Shavelle.[17,19] Finally, the simple stratification into 3 groups on the basis of ambulation is somewhat crude; a more refined analysis that takes account of the patient's mobility, feeding, and cognitive levels is possible using statistical methods, such as the Cox model.[20]

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