Trends in Hospitalization Associated With Traumatic Brain Injury

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In the United States, traumatic brain injury (TBI) is associated with the death of 51,000 people each year, about one third of all injury deaths. Traumatic brain injury is a cause of long-term disability that annually affects an estimated 70,000 to 90,000 people. Given these serious consequences and the large number of people affected, public health efforts to prevent the occurrence and mitigate the consequences of TBI have received increased attention in recent years.

Some success in TBI prevention and treatment efforts is suggested by an analysis of national mortality trends, which indicates a 22% decline in rates of death associated with TBI from 1979 to 1992. To our knowledge, there is no published study describing national trends in TBI-related hospitalizations over a comparable period, although comparisons of some studies in selected localities suggest the rate of these hospitalizations has declined more steeply. The purpose of this study is to describe long-term trends in TBI-associated hospitalization in the United States; to examine trends in the distribution of these injuries by age, sex, level of severity, and outcome; and to assess the implications of these trends with respect to public health and health care delivery.

Methods
To estimate annual rates of TBI-associated hospitalization, we analyzed data collected from 1980 through 1995 by the National Hospital Discharge Survey of the Centers for Disease Control and Prevention and the National Center for Health Statistics. Each year during this interval, the number of hospitals participating in the survey ranged from 400 to 494, and the sample size ranged from 18,000 to 276,000 hospitalizations for all causes. From 1980 through 1995, the annual number of cases of TBI identified in the sample ranged from 1611 to 3129. These TBI cases were identified using the Centers for Disease Control and Prevention case definition, ie, all hospital discharge records that contained—in 1 or more of 7 diagnostic data fields—an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnostic code in the ranges 800.0-801.9, 803.0-804.9, or 850.0-854.1. The National Hospital Discharge Survey used a multistage probability sampling design with weights applied to records to adjust for the probability of selection and nonresponse. These weighted records were used to generate US population estimates for the total number of hospitalizations associated with TBI each year. Relative SEs for annual population estimates, which...
ranged from 5% to 8%, were calculated using methods described by the National Center for Health Statistics.6

To classify the severity of TBIs among patients who were hospitalized, we used ICDMAP-90,9 a computer algorithm that maps ICD-9-CM diagnostic codes to a 6-level score approximating the Abbreviated Injury Scale (ICD/AIS).10 We then reclassified the ICD/AIS scores for the head region to a 3-level scale: ICD/AIS scores of 1 or 2 were defined as mild, 3 as moderate, and 4 through 6 as severe. We could not perform an extensive analysis of TBI incidence by cause of injury, because such data were incomplete; ICD-9-CM external-cause-of-injury codes (E codes) were present in only 10% to 47% of cases during the period of this study.

We used commercially available statistical software to calculate crude hospitalization incidence rates for each year, using as denominators the US Census estimates for the national civilian population at midyears during this interval. Generalized variance estimation functions that were provided by the National Center for Health Statistics were used to generate confidence intervals (CIs) for rates. Estimated crude hospitalization incidence rates by outcome status, injury severity, sex, and age by year, as well as average rates for the entire time interval, are presented. We compared 2-year aggregate data from 1980-1981 and 1994-1995 to measure changes between end points of the entire time interval, using z scores to test for differences in rates. To test for differences in percent change of hospitalization rates between categories of TBI severity, we calculated z scores using variance approximation methods.11

To compare estimated rates of TBI-associated hospitalization with TBI-associated emergency department (ED) visits, we used data collected by the National Hospital Ambulatory Medical Care Survey from 1992 (the first year of the survey) to 1995.12 Because the variance estimates associated with individual years of the survey were large, we calculated the average annual rate of TBI-associated ED visits for the interval 1992 to 1995 using methods described elsewhere.13 As with the analysis of National Hospital Discharge Survey data, TBI cases were identified among National Hospital Ambulatory Medical Care Survey records by searching all 3 diagnostic fields for ICD-9-CM codes consistent with the Centers for Disease Control and Prevention case definition. Traumatic brain injury–associated ED visits in 1995 that included a computed tomography (CT) scan evaluation of any body region were identified by the presence of a CT procedure code in the case record. Our analyses of National Hospital Ambulatory Medical Care Survey data included only those TBI-associated ED visits that did not lead to hospital admission or death.

RESULTS

From 1980 to 1995, the estimated annual incidence rate of hospitalization associated with TBI declined 51%, from 199 to 98 per 100 000 people (TABLE and Figure 1). The rates for males, which peaked at 260 per 100 000 in 1981, were consistently higher than the rates for females over the entire time interval. The average ratio of male-to-female rates was 1.8 (95% CI, 1.6-2.0), showing little variation during this time. The in-hospital mortality rate also showed little change during this period (Figure 1), with a mean of 5.3 (95% CI, 3.6-7.1) deaths per 100 000. External cause of injury was identified in 27% of TBI-related hospitalizations during this interval; 13% of injuries were attributed to motor vehicle crashes, 7% to falls, and 7% to all other known causes.

The decline in rates of TBI-related hospitalization varied among different age groups (Table). The decline was greatest among persons 5 to 14 years old and least among persons 65 years old or older.

The incidence rate of hospitalization for mild TBI declined significantly (P<.001) compared with the rates of hospitalization for moderate and severe TBI (Table and Figure 2). From 1980 to 1995, TBIs classified as mild declined 61%, from 130 to 51 hospitalizations per 100 000 people, TBIs classified as moderate declined 19%, from 26 to 21 hospitalizations per 100 000, and severe TBIs declined 90%.

### Table. Aggregate Incidence of TBI-Related Hospitalization by Outcome, Injury Severity, Sex, and Age, 1980-1981 vs 1994-1995*

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Overall</td>
<td>199 (179-219)</td>
<td>98 (86-110)†</td>
<td>−51</td>
</tr>
<tr>
<td>Nonfatal</td>
<td>193 (171-215)</td>
<td>93 (81-105)†</td>
<td>−52</td>
</tr>
<tr>
<td>Fatal</td>
<td>6 (4-8)</td>
<td>5 (3-7)</td>
<td>−17</td>
</tr>
<tr>
<td>Injury severity</td>
<td></td>
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</tr>
<tr>
<td>Mild</td>
<td>130 (112-148)</td>
<td>51 (43-59)†</td>
<td>−61$</td>
</tr>
<tr>
<td>Moderate</td>
<td>26 (22-30)</td>
<td>21 (15-27)</td>
<td>−19§</td>
</tr>
<tr>
<td>Severe</td>
<td>10 (8-12)</td>
<td>19 (13-25)†</td>
<td>90‡</td>
</tr>
<tr>
<td>Unknown</td>
<td>33 (27-39)</td>
<td>7 (3-11)†</td>
<td>−79</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>257 (226-288)</td>
<td>128 (110-146)†</td>
<td>−50</td>
</tr>
<tr>
<td>Female</td>
<td>145 (125-165)</td>
<td>71 (59-83)†</td>
<td>−51</td>
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<tr>
<td>Age, y</td>
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<tr>
<td>0-4</td>
<td>230 (187-273)</td>
<td>105 (68-142)†</td>
<td>−54</td>
</tr>
<tr>
<td>5-14</td>
<td>219 (184-254)</td>
<td>75 (50-100)†</td>
<td>−66</td>
</tr>
<tr>
<td>15-24</td>
<td>305 (262-348)</td>
<td>133 (106-160)†</td>
<td>−56</td>
</tr>
<tr>
<td>25-44</td>
<td>171 (146-196)</td>
<td>86 (72-100)†</td>
<td>−50</td>
</tr>
<tr>
<td>45-64</td>
<td>124 (102-146)</td>
<td>66 (50-82)†</td>
<td>−47</td>
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<tr>
<td>≥65</td>
<td>181 (150-212)</td>
<td>165 (134-196)</td>
<td>−9</td>
</tr>
</tbody>
</table>

*Data are from National Hospital Discharge Survey, National Center for Health Statistics, Centers for Disease Control and Prevention. Hospitalization rates (95% confidence intervals) are per 100 000 people. TBI indicates traumatic brain injury.
†Difference between intervals is statistically significant (P<.01).
‡Difference between percentage changes of incidence in mild and moderate categories is significant (P<.01).
§Difference between percentage changes of incidence in mild and severe categories is significant (P<.01).
TBIs classified as severe increased 90%, from 10 to 19 hospitalizations per 100,000. In 1995, the total number of hospitalizations for TBI was estimated at approximately 260,000.

For 1992 to 1995, the estimated annual rate of TBI-related visits to hospital EDs was 394 (95% CI, 357-430) per 100,000 people. Among all TBI-associated ED visits in 1995, the proportion that included a CT scan evaluation was 26%. Among ED visits in 1995 that were associated with TBI without diagnosis of injury to other body regions, 27% included a CT scan evaluation.

**COMMENT**

Several factors could account for the major decline in the estimated national rate of hospitalizations for TBI during the 16 years of the study period. First, during almost the same interval (1979-1992), the TBI-associated death rate decreased from 24.6 per 100,000 people to 19.3 per 100,000, a development that has been attributed in part to successes in injury prevention, especially those associated with motor vehicles. In our study, because external cause of injury was not consistently available in the National Hospital Discharge Survey data, we cannot directly assess any effects of injury prevention on trends in TBI-related hospitalizations during the study interval. Nevertheless, if success in injury prevention were the only factor contributing to the decrease in TBI-related hospitalization, then we would expect the decreases in rates of TBI-related hospitalization and TBI-related death to be similar in proportion; we might also expect a similar decrease in TBI-related hospitalization rates among all levels of injury severity. However, in contrast to the 22% decline in the TBI-associated death rate between 1979 and 1992, our data demonstrate a disproportionately greater decline in TBI-related hospitalization rates—51% during the interval of this study—with the decline found mainly among injuries of mild severity. Second, in the United States from 1980 to 1994, the rate of hospitalization for all causes declined 29%, suggesting a change in hospital practices for admissions. In a study of hospital service utilization and expenditures during this period, a reduction in inpatient services was associated with an increase in outpatient services, a shift attributed to the growing influence of prospective payment system reimbursement and managed care. Thus, hospital admission policies may now exclude a larger proportion of patients with mild TBI.

Hospital admission practices for TBI also may be affected by improved diagnostic technology. More frequent ED-based CT scanning may shift treatment of milder TBIs from hospital inpatient services to outpatient services. However, this effect may be limited, since only 26% of ED visits for TBI in 1995 included CT scan evaluations. A shift in TBI care toward the ED cannot be measured directly, because we are unable to compare rates of TBI-related ED visits with rates of TBI-related hospital admissions throughout the study period. However, the estimated rate of TBI-related ED visits in 1992 through 1995—approximately 1 million cases each year in the United States—indicates that about 80% of persons now evaluated for TBI are not admitted to hospitals.

The increased rate of TBIs classified as severe runs counter to all other trends found in these data. Three factors might account for this phenomenon. The increased number of cases classified as severe may be influenced by changes in ICD-9-CM coding practices during this period that decreased the assignment of nonspecific codes and increased the assignment of codes with specific severity information. Also, increased reliance on CT scanning and improved imaging during this study period may have increased the detection of traumatic intracranial lesions, again lead-

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**Figure 1.** Incidence Rates of TBI-Related Hospitalization in the United States, 1980-1995

**Figure 2.** Incidence Rates of TBI-Related Hospitalization in the United States by Category of Severity, 1980-1995

Data are from National Hospital Discharge Survey, National Center for Health Statistics, Centers for Disease Control and Prevention. TBI indicates traumatic brain injury. The shaded areas represent 95% confidence intervals.
ing to the assignment of more specific ICD-9-CM codes that indicate greater severity. In addition, improvements in trauma care during the interval of this study may have increased the proportion of critically injured persons who survive long enough to be admitted to hospitals, thereby increasing the number of cases classified as severe.

Our analysis has several limitations. The accuracy of our estimate of trends in the TBI severity distribution depends on correct ICD-9-CM diagnostic coding that is consistent over time among all hospitals in the sample. Limitations in the accuracy of diagnostic coding performed in hospitals have been noted since the beginning of this study period.10 Furthermore, coincident with the increased use of prospective payment systems, coding practices appear to have evolved toward increased use of codes denoting more specific and severe diagnostic categories.17-19 However, changes in coding practices documented during this period do not appear sufficient to account for the very large decline in rates of hospitalizations for TBIs classified as mild.

The accuracy of our estimate of trends in the TBI severity distribution also depends on the accurate classification of these injuries by ICDMAP-90 software. Misclassification of these data would affect our estimated relative proportions of TBI by level of severity more than the trends for each level of severity, because this classification algorithm is applied consistently to the data across all years examined.

CONCLUSION

Despite a substantial overall reduction of TBI-related hospitalization rates between 1980 and 1995, TBI continues to represent a major public health problem that calls for the application of more effective methods of injury prevention. The shift toward treating persons with less severe TBI as outpatients raises additional concerns. The proportion of those with mild TBI who experience effects later is unknown, although cognitive and emotional sequelae resulting in extended or long-term disability have been reported in a minority of cases.20-24 Our data provide no information about the number of persons seen in EDs or other outpatient facilities with such sequelae who may need follow-up care or evaluation. Assessing these needs and ensuring the availability of appropriate services is an important function of public health; additional studies are needed to address these issues.

REFERENCES