# Trends in Hospitalization Associated With Traumatic Brain Injury in a Publicly Insured Population, 1992–2002

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**Background:** Traumatic brain injury (TBI) is a leading cause of death and disability in developed countries. We document trends in TBI-related hospitalizations in Ontario, Canada, between April 1992 and March 2002, focusing on relationships between inpatient hospitalization rates, age, sex, cause of injury, severity level, and in-hospital mortality.

**Methods:** Information on all acute hospital separations in Ontario with a diagnosis of TBI was analyzed using logistic regression.

**Results:** Hospitalization rates fell steeply among children and young adults but remained stable among adults aged 66 and older. The proportion of TBI hospitalizations with mild injuries decreased from 75% to 54%, whereas the proportion with moderate injuries increased from 19% to 37%. Adjusting for other risk factors, in-hospital deaths were higher for injuries because of motor vehicle crashes than those because of falls. In-hospital death rates were stable for patients with moderate or severe injuries, but increased over time among those whose injuries were classified as mild, suggesting a trend toward more serious injury within the "mild" classification.

**Conclusions:** Hospitalizations for TBI involve fewer mild injuries over time and are highest in the oldest segment of the population.

**Key Words:** Traumatic brain injury, Epidemiology, Hospitalization, Age, Gender.

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Traumatic brain injury (TBI) is a leading cause of death and disability in developed countries.[1] There are currently no recent peer-reviewed comprehensive reports on hospitalization trends for TBI over time based on large populations in Canada. Our study aims to build upon previous reports in Canada and elsewhere that have focused on subpopulations, specific severity levels, or did not examine trends over time in detail.[2–8] Good baseline information on hospitalizations for TBI is important for planning of services. In addition, an evaluation of causes of TBI over time in representative population based samples is essential in targeting and evaluating prevention measures.

The current study examined data from a publicly insured population in the province of Ontario (2001 population 11.9 million) between April 1992 and March 2002. Our study included mild, moderate, and severe TBIs, providing one of the first large comprehensive population-based studies of trends in TBI-related hospitalizations and in-hospital mortality in this population across age categories and gender. Administrative databases provide a depiction of utilization by all residents and not just a subset either because of financial barriers (as in the United States) or to the opting-out of subgroups that might be covered under private insurance arrangements (as in parts of Europe). As a consequence, the unique data offer an opportunity to comprehensively assess the whole population "at risk."

## METHODS

In common with the other Canadian provinces, Ontario provides universal insurance that covers medically necessary physician and hospital services. Furthermore, all inpatient hospitalizations must be reported to a central registry. Thus, hospital care is available to all Ontarians on equal financial terms and the data reported here capture the entire set of hospitalizations for TBI.

We searched the Canadian Institute for Health Information (CIHI) Hospital Discharge Abstract Database for fiscal years (April 1 through March 31) 1992/1993 through 2001/2002 for all acute care hospital discharges of individuals who were hospitalized with a TBI.[8] A TBI was identified by the occurrence of an International Classification of Diseases, Ninth Revision (ICD-9) preadmission diagnosis of 800+, 801+, 803+ or 804+, or 850+ through 854+. We did not examine trends beyond this time frame because in April 2002, CIHI changed the coding system used in hospital discharge records, from ICD-9 to ICD-10-CA, and this change in coding scheme may affect results. We are not aware of any

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**Table 1** Trends in TBI Rates Per 100,000 Population, By Age and Sex

| Age (yrs) | Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|---|
| | Rate, 1992 | Rate, 2001 | Average Annual Change* | p Value† | Rate, 1992 | Rate, 2001 | Average Annual Change* | p Value† |
| 0–15 | 102 | 35.4 | −11% | <0.0001 | 170.4 | 64.2 | −10% | <0.0001 |
| 16–25 | 54.6 | 29.7 | −6.3% | <0.0001 | 135.6 | 78.5 | −5.8% | <0.0001 |
| 26–35 | 33.3 | 14.4 | −8.4% | <0.0001 | 78.4 | 47.3 | −5.2% | <0.0001 |
| 36–45 | 27.7 | 15.3 | −5.4% | 0.0012 | 60.7 | 42.3 | −3.5% | 0.0001 |
| 46–55 | 32.8 | 21.2 | −3.6% | 0.0026 | 56.4 | 44.9 | −2.3% | 0.0005 |
| 56–65 | 35.8 | 29.3 | −1.4% | 0.010 | 72.7 | 62.4 | −1.5% | 0.0049 |
| 66–75 | 62.1 | 62.4 | +01.1% | 0.53 | 98.8 | 94 | −0.1% | 0.076 |
| 76–85 | 156.4 | 148.7 | +0.1% | 0.51 | 191.2 | 184.8 | −0.3% | 0.057 |
| 86+ | 285.6 | 288.2 | +0.6% | 0.31 | 369.8 | 333.6 | +0.02% | 0.41 |

* Annual percentage change was defined as 100 × [rate in year (n + 1) − rate in year (n)]/rate in year (n).
† *p* value testing the hypothesis that there was a significant linear trend in the rate over time.
TBI indicates traumatic brain injury.

changes to the treatment of brain injuries which would be expected to alter the results.

Records with residence codes outside of Ontario were dropped. On average, 93.6% of the TBI hospitalizations in a year contained a valid Ontario residence code. Some patients had multiple hospitalizations annually and in this situation only the earliest was retained to avoid double-counting. Additionally, records from the previous year were examined to ensure the record retained was not a re-hospitalization. On average, 7.6% of the TBI hospitalizations in each year were readmissions.

The cause of injury was identified using ICD-9 external cause of injury codes (E codes). For study purposes, causes of injury were collapsed into three categories: motor vehicle crashes (MVCs), falls, and "other." Based on the Abbreviated Injury Scale (AIS) score, a severity score was assigned to each hospitalization. Scores were assigned using an algorithm that maps ICD-9 CM diagnostic codes to a 6-level score approximating the Abbreviated Injury Scale (ICD/AIS).[9] Scores were then collapsed into mild (AIS score less than 3), moderate (AIS score equal to 3), and severe (AIS score greater than 3) as has been done previously in the literature.[2] Additional comorbidities were captured by counting the number of supplementary comorbidities noted in the discharge record, after collapsing the comorbidities by ICD-9 chapter.[10]

Rates were calculated using the Statistics Canada intercensal population estimates for the appropriate year as denominators. Age- and age/sex-standardized rates were calculated using direct standardization with the 2001/2002 population as the reference. All rates are expressed per 100,000 population.

Logistic regression analysis was used to model the binary outcomes of moderate/severe injury (vs. mild injury) and in-hospital death (vs. discharged alive). All reported *p* values are two-tailed. *p* Values of less than or equal to 0.05 were considered statistically significant.

## RESULTS

### Trends in Rates

Between 1992/1993 and 2001/2002, the number of TBI hospitalizations per year fell from 8,831 to 5,999. Similarly, the age-sex standardized rate declined by almost 40% from 83.1 hospitalizations per 100,000 population in 1992/1993 to 50.4 per 100,000 in 2001/2002. Rates for males were consistently around 80% times larger than those for females. During the 10-year study period, age-standardized rates for both sexes declined equally, falling from 106.1 to 64.5 for males and from 60.6 to 36.7 for females.

These overall trends hide enormous sex- and age-related differences as shown in Table 1. In this table, for each age/sex combination, the rate for the first year (1992) and for the last year (2001), are given. As well, the average annual change is presented. The annual percentage change was defined as 100 × [rate in year (n + 1) − rate in year (n)]/rate in year (n). The nine values thus obtained were averaged to obtain the value presented in the table.

Rates dropped precipitously during the 10-year period for children with a milder decrease for young adults (aged 16–25 years old). Conversely, there was no change in the rates for adults aged 66 and older. Together these trends resulted in a substantial increase in the median age of hospitalized TBI patients, from 24 years in 1992/1993 to 41 years in 2001/2002.

Within a given age group, the ratio of male to female rates remained fairly constant over time, depending on the age group. Among children (aged 15 years and younger), the hospitalization rate for boys was, on average, 70% higher than the rate for girls; but among young adults (ages 16 to 25 years), rates were 160% higher for men than for women. After age 25, the higher rate for men over women fell with increasing age, returning to 70% by age 66 to 75 years. For seniors aged 86 years and older, men had a 30% greater hospitalization rate than women.

### Trends in Severity of Injury

Over time, TBI injuries resulting in hospitalization were more likely to be classified as moderate, instead of either mild or severe. Whereas in 1992/1993, mild injuries accounted for 75% of TBI hospitalizations, by 2001/2002 they accounted for only 54%. During the same time period, severe

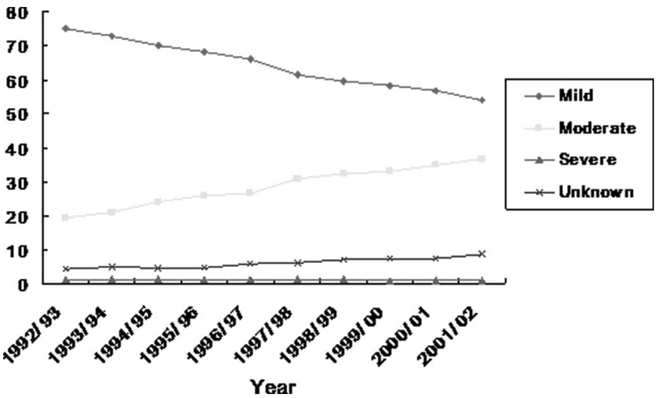


**Fig. 1.** *TBI Admissions in Ontario Acute Care Hospitals: % of admissions by level of severity based on AIS coding.*

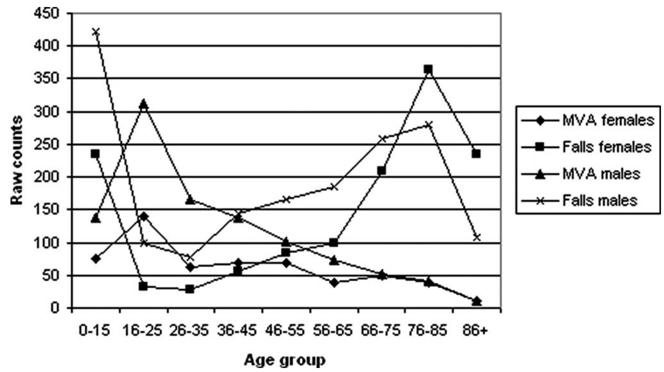


**Fig. 2.** *Raw counts by age, for MVCs and falls, 2001–2002.*

injuries fell from 1.3% of the total to 0.8%. This trend was statistically significant ($p = 0.0065$, Cochran-Armitage Trend test). The relative number of moderate injuries increased: in 1991/1992, moderate injuries accounted for 19% of the TBI admissions; by 2001/2002 this had increased to 37%. Injuries with unknown severity, likewise, increased from 4.4% of the total to 8.5% of the total (see Fig. 1).

### Time- and Age-Related Trends in Cause of Injury

Falls and MVCs together accounted for approximately 75% of the TBIs requiring hospitalization.

TBI hospitalization rates increase with age for falls but decrease with age for MVCs. Falls accounted for approximately 13% of the TBI hospitalizations among 16 to 25 year olds, but by age 86 years and older, 90% of the hospitalizations were attributed to falls. (In children, falls accounted for approximately 41% of TBI hospitalizations.)

Conversely, MVCs, on average, accounted for 61% of the TBIs in young adults (aged 16 to 25 years), and for 47% of the TBIs, on average, in adults aged 26 to 35 years, while falling to 5% of TBIs among people aged 86 years and older. (In children, they accounted for 31% of TBIs, on average.)

With the exception of the youngest (ages 0 through 15 years) and oldest (aged 86 years and older) age groups, the contribution of falls increased over time, while the contribution of MVCs decreased. Although small in degree, the trend was strong (the Spearman correlation between the percentage of hospitalizations which were due to MVCs and year was −0.72, $p = 0.018$). The contribution of falls increased, accounting for 45% of hospitalizations in 1992/1993 and 1993/1994, but 51% of hospitalizations in 2000/2001 and 2001/2002 (Spearman correlation = 0.90, $p = 0.0003$) (Fig. 2; Table 2).

### Factors Associated With In-Hospital Death

In-hospital death rates increased steadily between 1992/1993 (4.0% of people hospitalized with TBIs died) and 2001/2002 (7.5% death rate). This rise can be partially attributed to the increasing proportion of hospitalized TBI patients classified as moderate or severely injured. However, after adjusting for age, sex, and cause of injury, the probability of death did not increase over time among either those with moderate injuries ($p = 0.94$) or those with severe injuries ($p = 0.69$). The probability of death did, however, increase among those with mild injuries ($p < 0.0001$). For patients with mild injuries, the odds of death increased by a factor of 1.06 [95% confidence interval {1.04–1.09}] each year.

TBIs caused by MVCs were associated with a higher probability of inpatient death than TBIs caused by falls, after adjusting for other factors such as age and injury severity. For patients with a mild TBI, the odds of dying following a MVC (compared with the reference category of a fall) increased by 80% [$p = 0.0015$, 95% confidence interval for the odds ratio = {1.2–2.5}]; for patients with a severe TBI, the odds of dying following an MVC increased by a factor of 2.1 [$p = 0.0015$, 95% confidence interval for the odds ratio = {1.3–3.4}]. For moderate TBI patients, the odds of dying in-hospital did not depend significantly on the cause of the injury [odds ratio = 1.1, $p = 0.67$, 95% confidence interval = {0.8–1.5}].

Adjusting for the other covariates, females were less likely to die than males [odds ratio 0.79, 95% confidence interval {0.74–0.86, $p < 0.0001$}]. As expected, the probability of in-hospital death increased with increasing age.

## DISCUSSION

This research highlights the importance of monitoring hospitalization trends over time across groupings by age and gender. An understanding of the profile of consumers with TBI assists in planning, resource allocation, and staff training. It is clear that in this population sample, over time fewer milder injuries are being admitted, which is a trend found in US hospitals, with more persons seen on an outpatient or ER basis. Higher percentages of in-hospital deaths therefore have to be interpreted in this context.

Our study helps to quantify the TBI-related hospital burden associated with index admissions in the province of Ontario and identifies demographic groups that are at highest risk for TBI requiring hospitalization, and hence primary target groups for future prevention efforts. Trends over time were noted, which included a shift for most age groups in the

**Table 2** Within Each Age Group, Percentage of TBIs Resulting in Hospitalization Which Were Due to a Motor Vehicle Crash (MVC) and a Fall

| Age Group (yrs) | Fiscal Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1992/93 | 1993/94 | 1994/95 | 1995/96 | 1996/97 | 1997/98 | 1998/99 | 1999/2000 | 2000/01 | 2001/02 |
| MVC | | | | | | | | | | |
| 0–15 | 26.8 | 32.1 | 33.9 | 34.2 | 30.9 | 34.0 | 32.8 | 28.1 | 28.7 | 30.5 |
| 16–25 | 63.0 | 66.1 | 60.5 | 64.4 | 62.9 | 59.2 | 60.8 | 56.2 | 57.0 | 56.1 |
| 26–35 | 48.1 | 48.2 | 50.8 | 47.5 | 46.2 | 43.7 | 47.6 | 42.6 | 44.3 | 46.8 |
| 36–45 | 38.7 | 45.5 | 45.7 | 35.3 | 34.6 | 35.8 | 38.2 | 37.0 | 33.2 | 35.3 |
| 46–55 | 36.7 | 41.2 | 31.6 | 38.2 | 33.3 | 32.5 | 31.1 | 28.0 | 32.8 | 27.8 |
| 56–65 | 29.3 | 31.6 | 23.1 | 28.5 | 27.8 | 28.3 | 27.5 | 27.5 | 23.7 | 22.2 |
| 66–75 | 24.9 | 21.6 | 24.1 | 17.1 | 21.3 | 15.9 | 22.6 | 18.1 | 16.6 | 14.5 |
| 76–85 | 20.4 | 15.4 | 13.2 | 11.5 | 13.0 | 12.4 | 11.2 | 14.2 | 13.9 | 11.1 |
| 86+ | 4.9 | 9.9 | 3.0 | 5.6 | 3.5 | 1.5 | 4.1 | 6.1 | 4.8 | 7.6 |
| Falls | | | | | | | | | | |
| 0–15 | 43.7 | 39.5 | 39.3 | 37.9 | 40.5 | 39.0 | 37.1 | 40.2 | 47.2 | 43.7 |
| 16–25 | 10.8 | 6.9 | 13.4 | 12.0 | 13.4 | 10.2 | 13.3 | 12.8 | 10.6 | 17.3 |
| 26–35 | 23.2 | 16.8 | 19.5 | 20.1 | 21.7 | 23.0 | 20.7 | 24.4 | 27.9 | 17.3 |
| 36–45 | 31.1 | 30.4 | 28.6 | 36.8 | 37.5 | 34.9 | 33.2 | 36.6 | 38.5 | 30.2 |
| 46–55 | 42.4 | 36.1 | 42.8 | 38.2 | 46.3 | 44.9 | 46.0 | 45.8 | 50.2 | 49.0 |
| 56–65 | 53.7 | 49.3 | 59.0 | 54.8 | 56.0 | 53.5 | 58.8 | 58.9 | 57.2 | 58.3 |
| 66–75 | 66.3 | 67.4 | 67.2 | 71.7 | 71.5 | 74.2 | 66.4 | 70.6 | 73.0 | 77.3 |
| 76–85 | 74.0 | 77.6 | 81.9 | 81.0 | 80.4 | 81.5 | 83.9 | 81.5 | 81.0 | 83.7 |
| 86+ | 88.9 | 85.2 | 88.0 | 90.7 | 93.8 | 93.2 | 89.7 | 91.2 | 89.8 | 87.0 |

cause of injury from MVCs to falls, and a shift away from mild admissions, particularly for injuries caused by falls.

Because rates depend heavily on demographics and mode of injury, in addition to the period studied, comparisons with other jurisdictions are difficult; however, our findings are largely consistent with those reported in other studies.[2–8] Along with most other studies which examined trends over time, we found that the overall rate of hospitalization fell over the time period studied. In our data, hospitalization rates decreased both for mild and severe injuries, regardless of age, while the rates for moderate injuries increased.

In 1992/1993, 96% of Ontario patients who had a hospitalization involving a brain injury were discharged alive. By 2001/2002, this had fallen to 92.5%. Adjusting for other factors, the probability of death was higher for patients injured in a MVC. The increase in death rates over time was largely due to increasing severity of injury among those who were hospitalized, since the probability of death did not change over time for patients with moderate or severe TBIs. The probability of death increased over time for patients whose TBIs were classified as mild, suggesting that within the continuum of "mild" injuries, the severity of the overall injury was increasing over time and they were accompanied by other serious injuries.

Our study highlighted the high rates of hospitalization in the oldest segment of our population, which is also the fastest growing. This is also the most vulnerable group in terms of mortality and as such is an important area for prevention. This study also highlights issues for health resource planning as older adults have significantly slower and more costly progress in inpatient rehabilitation and have a lower rate of discharge to the community than younger survivors.[11]

This study examined complete data for a large population during a 10-year period. It included TBI resulting in hospitalization from both urban and rural areas, and in hospitals ranging from large teaching hospitals to small community hospitals. Estimates indicate that only 11% to 22% of TBIs result in a hospital admission, with the remainder treated only in the emergency department or by a family doctor, if at all.[1,12]

The decrease in TBI admissions particularly observed for young adults may be attributed to successful injury prevention efforts or policy changes. During this time frame, there were several initiatives aimed at injury prevention in Ontario. For instance, the Ontario administrative driver's suspension law was introduced in 1996 which required that anyone charged with driving with a blood alcohol concentration over the legal limit of 80 mg % or failing to provide a breath sample, would have their license suspended for a period of 90 days at the time the charge was laid. A recent study showed a 14.5% reduction in numbers of fatally injured drivers with no corresponding effect observed in control provinces due to better enforcement of drunk-driving laws.[13,14] A Graduated Licensing System was introduced in Ontario in 1994, which requires all new drivers to successfully pass through two stages of licensing before full licensure is granted. A recent article documented a significantly lower self-reported collision involvement among these new license holders.[15] In addition, fewer bicycle-related injuries have been documented after legislation mandating helmet use for children aged under 18, which was introduced in this time period.[16]

This decrease may be due to changes in medical practice which has shifted treatment of milder TBIs from hospital based services to outpatient services.[2] Likewise, the decrease in mild TBI hospital admissions may be related to increased numbers of people seen only in emergency departments and physician offices. An estimate of the number of these TBIs may be obtained by examining data on emergency departments and visiting physician offices to obtain a complete picture of the incidence of TBI. Our data on TBI deaths are in hospital deaths only. Data on fatalities involving TBI would have to be obtained from the data files of the Office of the Chief Coroner of Ontario. The computerized data files from this office, however, do not code ICD codes, so therefore a hand search would be necessary. Data from death certificates from the Office of Vital Statistics may also provide additional information; however, this information cannot be linked via a common identifier in Canada such as the Social Security Numbers in the United States.

Ontario residents injured and hospitalized elsewhere are not captured in the hospital discharge database; therefore, the true rate of hospitalization for TBIs in the Ontario population was underestimated. Conversely, patients may be hospitalized for multiple injuries, resulting in an overestimation of the true incidence of TBIs severe enough to require hospitalization.

Administrative data used in this study may be missing important information as it was not initially collected for research purposes. We were not able to assign a severity rating to 6% of the injuries. During the study, there was concern about upcoding of hospital discharge records, such as the inclusion of unimportant comorbidities to make patients look sicker to increase hospital funding. The decline in TBIs classified as severe, the increase in death rates for those with mild injuries, and the lack of a trend in the probability of death over time for patients with moderate and severe injury appears to argue against this concern; if there was upcoding, we would expect death rates to decrease over time for patients with moderate and severe injuries.

A more complete picture of system resource use by patients could be obtained by linking hospital admission data to data from emergency room admissions especially for milder injuries. In addition, we recognize that there are segments of the population at high risk for injuries such as prisoners and aboriginal peoples served by federal agencies, who may not be captured in provincial health insurance data.

Reliable estimates of rates of hospitalization for TBI and an understanding of their trends are important in the health services planning. Prevention programs cannot be properly targeted without reliable data about the incidence, demography, and cause of injuries. Accurate baseline information is required to analyze the effects of changes to hospital admission practices, or motor vehicle and other safety measures. Overall rates and severity are specific to age, sex, and causes of injury; therefore, overall summaries are not useful in detecting the effects of specific interventions. Although there are some consistencies across different regions, the experience of TBI survivors varies considerably with jurisdiction, making the examination of local information essential.

Additional studies are needed to capture TBIs from emergency department visits and physician office encounters, supplemented by self-report of TBIs from national surveys. It was beyond the scope of this article to examine health service utilization after initial hospitalization, such as numbers of persons admitted to rehabilitation hospitals, skilled nursing homes, and chronic care as well as readmission. This is an important area for future investigation. Prevention efforts should continue to target highest risk groups such as children/young adults and older adults as causes of this potentially devastating injury are largely preventable. In addition, resources at inpatient facilities should be prepared to manage overall more severe cases of TBI and older adults with TBI.

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