Severe Traumatic Brain Injury in a Large Canadian Health Region

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ABSTRACT: ***Background:*** Although severe traumatic brain injury (sTBI) is a devastating condition with tremendous public health implications, the epidemiology of this disease has not previously been described in Canada. We sought to define the incidence, risk factors and outcome of patients suffering sTBI in a large Canadian region. ***Methods:*** A population-based surveillance cohort design was utilized to identify all Calgary Heath Region residents who were victims of trauma with an injury severity score ≥12. Subsequent application of a specific sTBI case definition defined the final cohort. ***Results:*** The annual incidence of sTBI was 11.4 per 100,000 population. The incidence of sTBI was significantly higher for males as compared to females [17.1 vs. 5.9 per 100,000; relative risk (RR) = 2.91, 95% confidence interval; 2.17, 3.94; p<0.0001]. There was a striking increase in the annual age specific population incidence of sTBI observed among those older than 74 years of age. The relative risk among the highest risk group of elderly (>85 years) males as compared to the lowest risk female group (50-64 years) was 19.78 (95% CI; 6.27, 62.3; p<0.0001). One hundred and eight patients died prior to hospital discharge for a mortality rate of 5.1 per 100,000 per year. ***Conclusions:*** Severe traumatic brain injury is common among residents of the Calgary Health Region and is associated with a high mortality rate. Males and the elderly are at the highest risk for acquiring sTBI and may represent target groups for preventive efforts.

RÉSUMÉ: Étude de population sur les traumatismes crâniens sévères dans une vaste région sanitaire canadienne. ***Introduction:*** Bien que les lésions cérébrales sévères (LCS) causées par un traumatisme crânien aient des conséquences dévastatrices et un impact important en santé publique, l'épidémiologie de cette affection n'a jamais été décrite au Canada. Le but de cette étude est de déterminer l'incidence, les facteurs de risque et l'issue des patients atteints de lésions cérébrales traumatiques graves dans un grand territoire canadien. ***Méthodes:*** Une étude de cohorte a été utilisée pour identifier tous les résidents de la région sanitaire de Calgary qui ont été victimes d'un traumatisme dont le score de sévérité des lésions était de 12 ou plus. Les cas inclus dans la cohorte étaient ensuite sélectionnés selon une définition spécifique des LCS. ***Résultats:*** L'incidence annuelle des LCS était de 11,4 par 100,000 de population. Elle était légèrement plus élevée pour les hommes, soit 17,1 par rapport à 5,9 pour les femmes et leur risque relatif était de 2,91 (IC 2,17 à 3,94; p < 0,0001). Chez les sujets de plus de 74 ans, on a observé une incidence élevée de traumatismes crâniens. Le risque relatif était de 19,78 (IC 6,27 à 62,3; p < 0,0001) dans le groupe ayant le niveau de risque le plus élevé, soit les hommes âgés (> 85 ans) comparé à celui des femmes ayant le risque le plus faible (50 à 64 ans). Cent huit patients sont morts pendant l'hospitalisation, soit un taux de mortalité annuelle de 5,1 par 100,000. ***Conclusions:*** Les lésions cérébrales par traumatisme crânien sévère sont fréquentes parmi les résidents de la région sanitaire de Calgary et sont associées à une mortalité élevée. Les hommes et les personnes âgées sont les groupes les plus à risque et constituent des groupes cibles pour les interventions à visée préventive.

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Traumatic brain injury is the single most important injury contributing to traumatic mortality and morbidity[1] and is recognized as a critical health problem.[2] Severe traumatic brain injury (sTBI), although comprising only 10% of all brain injuries,[3] contributes the greatest proportion of deaths,[2,4] disability,[4-7] and cost related to traumatic brain injury[4,6] both in Canada[8,9] and around the world.[2,7] Understanding the occurrence

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and risk factors of sTBI is important for establishing the burden of disease and for identifying means of prevention or early treatment. This is best accomplished using data derived from a population-based cohort. Population-based statistics allow for accurate international comparison and can be used in conjunction with other population data such as environmental exposures, driving age, legal drinking age, speed limits and firearm ownership.[10] The purpose of this study was to define the incidence, risk factors and outcome of patients suffering from sTBI, within a large Canadian region, by a population-based cohort analysis.

Methods

Patient population

The Calgary Health Region (CHR) is a fully integrated, publicly funded health system that provides virtually all medical and surgical care to the residents of the cities of Calgary and Airdrie and approximately 20 nearby small towns, villages, and hamlets. In the CHR, adult trauma services are regionalized to the Foothills Medical Centre that is the only adult tertiary care trauma center servicing southern Alberta, Canada. All adult (≥18 years of age) victims of trauma with an Injury Severity Score (ISS) ≥12 who also suffered sTBI while resident in the CHR between April 1, 1999 and March 31, 2002 were included.[11] Severe traumatic brain injury was defined as a traumatic brain injury resulting in at least one of 1) an initial resuscitated (systolic blood pressure > 90 mm Hg and SaO_2 > 90%) Glasgow Coma Score (GCS) of 8 or less at first contact with medical services, or 2) a postresuscitation GCS at presentation to the trauma centre of 8 or less in the absence of sedation, 3) the requirement for intracranial pressure (ICP) monitoring, or 4) the presence of clinical or radiographic herniation. In our institution, ICP monitoring is never used for moderate or mild head injury and is indicated for those who remain comatose on repeated neurological examinations or have radiographic evidence of intracranial hypertension. The herniation criteria required uncal or transtentorial herniation confirmed on CT scan or an episode of unilateral or bilateral pupillary dilatation and a neurosurgeon's or intensivist's documented diagnosis of herniation syndrome. A CHR resident was defined as an individual with a home address listed within the boundaries of the CHR.[12] This study was approved by the ethics review board at the University of Calgary and CHR.

Study Protocol

An active population-based surveillance cohort design was utilized. All patients treated at the Foothills Medical Centre for traumatic injuries associated with an ISS≥12 were prospectively identified and charts were reviewed for clinical information. The CHR Health Information Services database that records detailed administrative information on all patients admitted to any acute care facility within the CHR was also used in an attempt to identify any trauma cases admitted to other hospitals in the region. Data were then merged from these two sources. Within this database those suffering sTBI were identified for inclusion in this study by application of the study enrollment criteria.

Statistical Analysis

All analyses were performed using Stata version 7.0 (Stata Corp., College Station, TX). Where missing data occurred values were not replaced. Prior to analysis all variables were assessed for underlying distribution qualitatively using histograms. Means with standard deviations (SD) and medians with interquartile ranges (IQR) were used to describe normally and non-normally distributed variables, repectively. Differences in proportions were compared using Fisher's exact test, medians using the Mann Whitney U test, and means using the Student's t-test. Annual incidence rates were compared using the normal approximation for the comparison of Poisson counts. Category specific rates of incidence and relative incidence were calculated using the numbers of cases observed in the study as numerator and local population demographic data as denominator data. The proportion of urban residents in the CHR was estimated at 94.5% based on 2001 Canadian national census information.[13]

Results

Incidence

A total of 242 patients were identified to have suffered sTBI during the study period for an overall annual adult incidence rate of 11.4 per 100,000 population (adult CHR population 707,683). The diagnosis of sTBI was based on postresuscitation GCS at time of first contact with medical services criteria in 181 patients (75%), postresuscitation GCS at Foothills Medical Centre in 11 patients (5%), ICP monitoring in 30 (12%), and the presence of herniation in 20 patients (8%). The annual incidence rates (per 100,000 population) were stable at 12.6 (87 cases), 10.3 (73 cases), and 11.3 (82 cases) for 1999-2000, 2000-2001, and 2001-2002, respectively (p=0.5). Significant quarterly variation in sTBI incidence was observed with the highest incidence occurring between July-September [75 cases (31%)] and the lowest between January-March [39 cases (16%), p=0.02] (Figure 1).

Age and Gender

The overall mean (±SD) age was 44 (±20) years and it was significantly lower for males [42 (±19), n=179] as compared to females [49 (±22), n=63; p=0.02]. The annual incidence of sTBI was significantly higher for males as compared to females [17.1

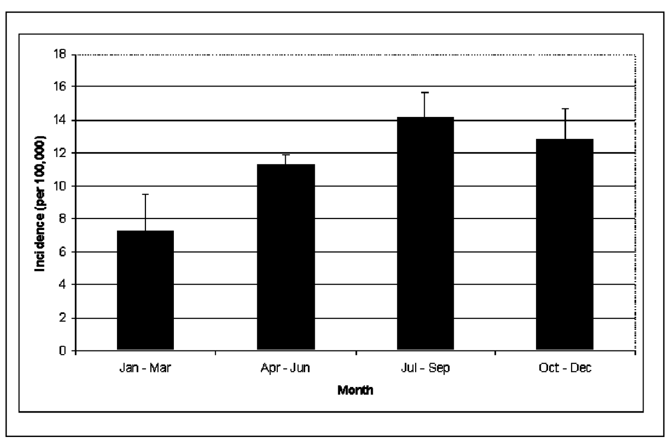

Figure 1: *Quarterly incidence of severe traumatic brain injury in the Calgary Health Region (April 1999 to March 2002). Error bars represent standard error of the mean.*

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Table 1: Characteristics of severe traumatic brain injury by etiology of injury in the Calgary Health Region (April 1999 to March 2002).

Primary accident etiology	Number of cases (%)	Mean Age (±SD) Years	Intentional Causality (%)	Overall Number of Deaths (%)
Motor vehicle crash	113 (47)	39 (±19)	1 (1)	48 (42)
Fall or jump	81 (34)	55 (±21)	6 (8)	38 (47)
Struck by object or animal	29 (12)	33 (±8)	21 (54)	7 (24)
Other	19 (8)	38 (±14)	11 (75)	15 (79)
Total	242 (100)	44 (±20)	39 (17)	108 (45)

vs. 5.9 per 100,000; relative risk (RR) = 2.91, 95% confidence interval (CI); 2.17, 3.94; p<0.0001]. This increased risk for males was consistently observed across all age groups except for the group 65-74 years for which there was no significant difference in incidence rates (p=1.0). There was a striking increase in the annual age specific population incidence of sTBI observed among those older than 74 years of age as shown in Figure 2. The relative risk among the highest risk group of elderly (>85 years) males as compared to the lowest risk female group (50-64 years) was 19.78 (95% CI; 6.27, 62.3; p<0.0001).

Etiology of Severe Traumatic Brain Injury

Three most common etiologies of sTBI accounted were motor vehicle crashes, falls or jump, and struck by an object or animal with incidence rates (per 100,000 population) of 5.3, 3.8, and 1.4, respectively. Penetrating trauma was uncommon occurring in only 4% of cases. The differing etiologies and their associated characteristics and outcomes are shown in Table 1. The majority [196 (81%)] of cases of severe traumatic brain injuries were non-intentional for an incidence of 9.2 per 100,000 per year. Intentionally caused episodes included suicide [15 (6%)], assault [19 (8%)], and homicide [5 (2%)] for rates of 0.7, 0.9, and 0.2 per 100,000 population, respectively. Seven cases (3%) were not classified for intent of injury. Significant overall relationships among age and gender with intention of injury were observed.

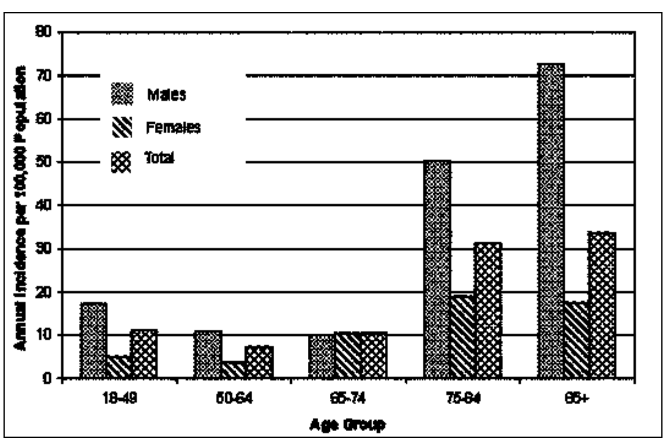

Figure 2: Age and gender specific incidence of severe traumatic brain injury in the Calgary Health Region (April 1999 to March 2002).

People in the age group 18-49 were far more likely to suffer from intentional injuries as compared to other age groups (35/159 vs. 4/76; RR=4.18, 95% CI; 1.54, 11.35; p=0.001). The majority of suicides (11/15) and all homicides (5/5) and assaults (19/19) occurred in this youngest age group. In contrast, 32/33 (97%) of traumatic brain injuries occurring in those aged 75 years and older were accidental. Males were significantly more likely than females to suffer intentional injury (35/174 vs. 4/61, RR= 3.07, 95% CI; 1.13, 8.28; p=0.01). Six percent (15/241) of severe traumatic brain injuries were work related and seven of these injuries were fatal (47%).

Prehospital and Hospital Course

The mode of initial transport from the scene of the accident was ground ambulance in 222 (92%) cases, and helicopter in two (5%) cases. Secondary transport from another healthcare institution occurred most commonly by helicopter in 18 (95%) of cases with ground ambulance used in the remainder. Median (IQR) time from arrival of emergency medical personnel at the scene of the accident to arrival of the patient at Foothills Medical Centre was 68 (49, 86) minutes. A total of 58 (24%) of patients required operating room visits for neurosurgical procedures. Time to initial neurosurgical procedure was available for 42 patients. Median (IQR) time to operation was 4.8 hours (3.4, 10.7). Seventy-eight percent of admitted patients required admission to a multidisciplinary intensive care unit for a median (IQR) length of stay of four (1, 9) days. Forty percent of patients admitted to ICU underwent ICP monitoring. The overall median (IQR) hospital length of stay was 6.7 (0.9, 23.9) days. Hospital length of stay was significantly longer for survivors [median (IQR), 18.4 (19.7, 38.0)] than for nonsurvivors [median (IQR), 0.8 (0, 3.9); p<0.0001].

Injuries

The incidence of each type of intracerebral injury as reported by the attending neuroradiologist is detailed in Table 2. The most common intracerebral injuries were subdural hematoma and traumatic subarachnoid hemorrhage occurring in 49% and 44% of patients, respectively. Epidural hematoma was the least common injury occurring in 10% of patients. Sixty-two patients (26%) had no intracranial pathology identified. One, two, three, four and five intracranial injury types were found in 18%, 17%, 21%, 16% and 3% of patients, respectively. Forty-eight percent of patients had noncerebral injuries. Injury Severity Scores ranged from 13 to 75 and were a median (IQR) 25 (24, 35) points. Chest, abdominal and extremity injuries occurred in 34%,

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Table 2: Intracerebral injuries in patients with severe traumatic brain injury and abnormal CT scans in the Calgary Health Region (April 1999 to March 2002)†

Finding on CT	Number of Cases (%)	Incidence (per 100,000)	Overall Number of Deaths†† (%)
Subdural Hematoma	119 (49)	5.6	45 (38)
Epidural Hematoma	25 (10)	1.2	11 (44)
Diffuse Axonal Injury	48 (20)	2.3	21 (44)
Traumatic Subarachnoid Hemorrhage	107 (44)	5.0	46 (43)
Parenchymal Contusion	89 (37)	4.2	35 (39)
Parenchymal/ Ventricular Hemorrhage	76 (31)	3.6	37 (49)

†Patients may have had more than one cerebral injury.
††Case fatality was not adjusted for covariates.
CT=Computed Tomography.

Table 3: Case fatality of intentional (suicide, assault and homicide) and nonintentional injuries by age and sex.

		Case Fatality Intentional Injury	Case Fatality Nonintentional Injury
Age	<40	10/27 (37%)	32/89 (36%)
	≥40	7/12 (58%)	54/107 (50%)
Sex	Female	4/4 (100%)	29/57 (51%)
	Male	13/35 (37%)	57/139 (41%)

12% and 32% of patients, respectively. Severe extracerebral injuries, as defined by a maximum abbreviated injury score ≥ 3, were present in 37% of patients.

Mortality

A total of 108 (45%) individuals died at some point between the assessment by trauma services and discharge from hospital for an overall annual population mortality rate of 5.1 per 100,000. There was no significant difference in mortality among the four diagnostic criteria for sTBI (p=0.9). Males experienced lower hospital mortality compared to females (RR=0.73, 95% CI; 0.55, 0.98; p=0.04). Overall, intentionally caused injuries were not associated with a significantly increased hospital mortality as compared to accidental injuries (17/39 vs. 86/196, RR=0.99, 95% CI; 0.67, 1.47; p=1.0). Subgroup analysis (Table 3) revealed that although female patients were less likely to sustain an intentional injury, hospital mortality was higher for females with intentional injury (4/4) than for males with intentional injury (13/35, p=0.03). The postresuscitation GCS was available for 224 patients. The median (IQR) GCS was 4 (3, 7) points and was significantly associated with hospital mortality. Patients with a postresuscitation GCS of 3 or 4 were twice as likely to suffer in hospital mortality as those with higher scores (69/121 vs. 29/103; RR 2.03, 95% CI: 1.43, 2.86; p<0.0001). Those patients who underwent a neurosurgical procedure did not experience a significantly different mortality compared to patients who did not (RR=0.91, 95% CI; 0.64, 1.30; p=0.6). For those patients surviving at least 24 hours, the number of different injuries identified on computed tomography was significantly associated with hospital mortality. Mortality was 12% when no injuries were found compared to 48% and 50% when four and five cerebral injuries were recognized, respectively. The presence of chest, abdominal or extremity injury was not associated with increased mortality. Patients admitted to ICU were at greater risk of dying than those admitted to the high dependency unit or ward (RR=2.62, 95% CI; 1.21, 5.67; p=0.005). If ICU patients with less than 48 hours length of stay were excluded, that is patients with catastrophic injury, mortality was 31%.

Discussion

Following the recognition of the importance of traumatic brain injury to traumatic morbidity and mortality,[1,14,15] the development of widespread trauma surveillance programs, changes in public policy and improved prevention programs have contributed to a decline in fatal traumatic brain injury for the second consecutive decade.[2,16] Studies of assessment of intervention strategies after acute severe brain injuries have demonstrated decreased mortality and improved outcome in centres where more aggressive prehospital care with early intubation was documented[5,17] and monitoring of intracranial hypertension was completed.[5,18] Despite the establishment of effective triage programs, best evidence-based protocols for the treatment of severe brain injured patients,[19] and progress in the management of secondary complications of sTBI, significant regional differences in practice continue to exist.[20] Understanding the risk factors for poor outcome of patients surviving to hospital care is important, since it is for these patients that intervention is possible and resources will be required.

Many epidemiological studies of head injury exist.[8,14,15,21-28] Few, however, are population-based or stratified based on severity and therefore reflect the true burden of sTBI on the population. This is the first population-based cohort study of sTBI in a large Canadian health care region. A literature search revealed several other Canadian epidemiological studies of head injuries,[8,9,25] but only one population-based study that did not stratify according to severity of injury.[24] In comparison with other population-based studies, the incidence in the CHR was lower than the 14 per 100,000 reported by Kraus et al[14] in San Diego County. However, patients dead on arrival or dying in the emergency room were not included in the San Diego study, and, as a result, the actual difference in incidence between the two studies may be greater. Tiret et al,[23] reported a significantly higher incidence of severe brain injury in Aquitaine, France, of 24 per 100,000, which had decreased to only 17 per 100,000 10 years after the initial study.[22,23] Severe brain injury was defined using head region Abbreviated Injury Scores (HR-AIS) of 4 or 5. Glasgow coma scores scores >8 were documented in 93 and 39% of these study cohorts while only 15% of our patients had a postresuscitation GCS >8. Therefore, the studies from Aquitaine potentially included a significant larger proportion of milder

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brain injuries. Bouillon et al[28] reported a “population-based” study of sTBI in Cologne, Germany. The absolute annual incidence was reported as 93. The population of Cologne was identified as 1 million but an exact rate per 100,000 persons was not given suggesting the true population at risk was not known. Further, nonresidents of Cologne were not excluded from the analysis which may falsely overestimate the true rate. Thus, it is unclear if the report by Bouillon is truly population-based and invalidates comparisons with our study.

Case-fatality rates in severe brain injured patients surviving to hospital care remains high and is reported from 30%[22] to 58%[14] which is similar to the case-fatality rates of 45% identified in our study. If ICU patients with less than 48 hours length of stay are excluded, that is patients with catastrophic injury, mortality is 31% and may better reflect the outcome for patients in which aggressive management was warranted. Population adjusted mortality rates in our study and that by Masson et al,[22] both of which reflected only those patients surviving to hospital care, were the same at 5.1 per 100,000. Low GCS in our study were significantly associated with hospital mortality which is consistent with several previous studies.[19,29] Although female sex was associated with a higher case fatality than male sex, this is likely explained by the marked discrepancy in incidence rates in the younger age groups. Although we were unable to identify a difference in case fatality among cerebral injury type, it is important to recognize these data were not subjected to adjustment for covariates. The presence of a head injury in a major trauma patient has previously been shown to be associated with significantly greater mortality compared to patients in which no head injury was present.[1] Although severe extracranial injuries were present in greater than one third of all patients in our study, we were unable to detect an increased contribution to mortality possibly due to our relatively small population.

Although we employed a population-based design which most accurately reflects disease incidence, associated risk factors and outcome, a few limitations in our methodology exist and warrant discussion. Although we prospectively identified all patients with major trauma, and entered into trauma database, the classification of the severity of the head injury was made retrospectively.Aprior audit of sTBI in our institution had noted some missing GCS data in patients who had clearly sustained a sTBI based on their radiographic findings and clinical course. This most commonly occurred due to intubation in the field during resuscitation. Therefore, in addition to standard GCS criteria for the classification of a severe head injury, we included ICP monitoring and clinical or radiological herniation. Although this unique case definition makes comparisons with other studies problematic, our primary concern was complete case ascertainment. Residents of the CHR who may have sustained a severe brain injury outside of the region were not accounted for; however, this likely represents a small number of cases because of the large referral area which is served. Patients who failed to survive to medical care were excluded and as a result, estimates do not reflect the true societal impact of sTBI. However, patterns and risk factors associated with the patients surviving to hospital care represent those patients in which intervention is possible from prehospital to hospital setting.

Severe traumatic brain injury is common and associated with consumption of considerable health resources.[30] Despite recent advances in the care of patients with sTBI, mortality remains unacceptably high. Males and the elderly are at highest risk and represent target groups for preventive efforts. To reduce the tremendous burden of this devastating disease, it is imperative regional prevention programs are further developed and outcomes-based clinical research is facilitated.

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