ORIGINAL ARTICLE

Traumatic Brain Injury in the Workplace

Michael Paci, Claire Infante-Rivard, Judith Marcoux

ABSTRACT: ***Objectives:*** Work-related traumatic brain injuries (TBIs) are not well documented in the literature. Published studies mostly rely on worker databases that fail to provide clinically relevant information. Our objective is to describe the characteristics of hospitalized patients and their work-related TBI. ***Methods:*** We used the Québec provincial trauma and TBI program databases to identify all patients with a diagnosis of work-related TBI admitted to the Montreal General Hospital, a level 1 trauma center, between 2000 and 2014. Data from their medical records were extracted using a predetermined information sheet. Simple descriptive statistics (means and percentages) were used to summarize the data. ***Results:*** A total of 285 cases were analyzed. Workplace TBI patients were middle-aged (mean, 43.62 years), overwhelmingly male (male:female 18:1), mostly healthy, and had completed a high school level education. Most workers were from the construction industry; falling was the most common mechanism of injury. The majority of patients (76.8%) presented with a mild TBI; only a minority (14%) required neurosurgery. The most common finding on computed tomography was skull fracture. The median length of hospitalization was 7 days, after which most patients were discharged directly home. A total of 8.1% died of their injuries. ***Conclusions:*** Our study found that most hospitalized victims of work-related TBI had mild injury; however, some required neurosurgical intervention and a non-negligible proportion died of their injury. Improving fall prevention, accurately document helmet use and increasing the safety practice in the construction industry may help decrease work-related TBI burden.

RÉSUMÉ: **Traumatisme crânio-cérébral en milieu de travail.** ***Objectifs:*** Il existe peu de littérature sur les traumatismes crânio-cérébraux (TCC) en milieu de travail. Les études publiées s'appuient principalement sur les bases de données de travailleurs qui ne fournissent pas de renseignements cliniques pertinents. Notre objectif était de décrire les caractéristiques des patients hospitalisés pour un TCC ainsi que le TCC qu'ils ont subi au travail. ***Méthodologie:*** Nous avons utilisé la base de données du Registre des traumatismes du Québec ainsi que celle du Programme de traumatisme crânio-cérébral pour identifier tous les patients chez qui un diagnostic de TCC subi en milieu de travail a été posé et qui ont été hospitalisés à l'Hôpital général de Montréal, un centre de traumatologie de niveau 1, entre 2000 et 2014. Nous avons utilisé une fiche de renseignements préétablie pour recueillir les données des dossiers médicaux de ces patients et nous avons utilisé des statistiques descriptives simples (moyennes et pourcentages) pour résumer les données recueillies. ***Résultats:*** Nous avons analysé les données de 285 patients. Les patients ayant subi un TCC en milieu de travail étaient d'âge moyen (moyenne de 43,62 ans) et majoritairement des hommes (18 hommes pour 1 femme) en bonne santé qui avaient complété des études secondaires. La plupart étaient des travailleurs de la construction et une chute était la cause la plus fréquente du traumatisme. La majorité des patients (76,8%) ont consulté pour un TCC léger et seulement une minorité de patients a dû subir une intervention neurochirurgicale. La constatation la plus fréquente à la tomographie assistée par ordinateur était une fracture du crâne. La durée médiane d'hospitalisation était de 7 jours et la plupart des patients sont retournés directement à leur domicile au moment du congé hospitalier. En tout, 8,1% des patients sont morts de leurs blessures. ***Conclusions:*** Selon notre étude, la plupart des victimes de TCC en milieu de travail qui sont hospitalisés, avaient subi une blessure légère. Cependant, certains ont dû subir une intervention neurochirurgicale et une proportion non négligeable de ces accidentés sont morts de leurs blessures. Une amélioration de la prévention des chutes, une documentation fidèle de l'utilisation du casque et une augmentation des mesures de sécurité dans l'industrie de la construction pourraient aider à diminuer le fardeau des TCC en milieu de travail.

Keywords: brain injury - traumatic, head trauma, neurotrauma

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Traumatic brain injury (TBI) can be defined as a head injury that leads to "an alteration of brain function, [presenting as] confusion, altered level of consciousness, seizure, coma or focal sensory or motor neurologic deficit." [1] Yearly incidence of TBI in the United States is estimated to be between 180 and 250 cases per 100,000 population, with patients more likely to be young children, young adults, or elderly.[1] Motor vehicle accidents and falls are the two most common mechanisms of injury leading to TBI.[1] TBI carries significant morbidity and mortality, and patients who survive can be left with permanent limitations and neurological deficits.[2]

Workers who have sustained injury in the workplace form a distinct subgroup of TBI patients with different injuries resulting from high-energy processes and special hazards.[3] The yearly incidence is estimated at 19.8 per 100,000 workers with a mortality slightly >10%.[4,5]

Coleman[6] was one of the first to study TBI in the workplace. Workplace TBI cases occurring in Britain in 1981 and 1982 were analyzed using data from the Health and Safety Executive. A total of 19,548 cases were identified showing that the main industries in which they occurred were public administration and defence (including police officers and firemen but not the military), construction, mining, distributive trades, and professional and scientific services. The main injury mechanism recorded was being

From the Departments of Neurosurgery (MP, JM) and Epidemiology (CI-R), Biostatistics and Occupational Health, McGill University, Montreal, Canada; Department of Neurosurgery (JM) McGill University Health Center, Montreal, Canada

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Correspondence to: Judith Marcoux, McGill University Health Centre - Neurosurgery, 1650 Cedar Ave, Montreal, Quebec H3G 1A4, Canada. Email: judith.marcoux@mcgill.ca.

struck by an object. Among these cases, 190 died from their TBI, representing 21% of all work-related deaths for that period. Konda et al[7] looked at all emergency department visits for work-related TBI from 1998 to 2007 using the National Electronic Injury Surveillance System in 67 US hospitals. They found an annual rate of nonfatal work-related TBI of 4.3 per 10,000 full-time equivalent workers. The highest rate of nonfatal TBI was seen in males and younger workers. The main cause of TBI in younger workers was contact with objects (struck by building material) and equipment, whereas the main source of TBI for older workers was falls.

Kim et al reviewed data from the Ontario Trauma Registry to compare workplace TBI with nonworkplace TBIs occurring between 1993 and 2001.[5] They identified 12,991 cases, of which 950 (7.3%) were work-related. In comparison with nonworkplace TBI, the former cases were found to be slightly older (average age, 39.8 years vs 35.6 years), more likely to be male (male:female ratio of 16.1:1 vs 2.8:1), and less likely to have psychiatric comorbidity (6.3% vs 12.4%). The main industries in which workplace TBI occurred were construction, manufacturing, sales and services, primary industry, and transportation. Unlike Coleman,[6] Kim et al[5] found that the main mechanism of injury was falls (45.3%), followed by motor vehicle accidents (20.7%). They also observed that the number of motor vehicle accidents causing workplace TBI decreased with increasing worker age category. A recent systematic review found that younger and older workers were more at risk of TBI. The main cause of TBI was falls, and the workplaces more at risk were construction industries and primary industries (e.g. agriculture, forestry, mining).[8]

Given that the construction industry presents very high-energy processes and was previously identified as a major source of workplace TBI,[5,6] it is relevant to review the risks in this specific industry. Colantonio et al[9] reviewed data from the Ontario Workplace Safety and Insurance Board from 2004 and 2005 for workplace TBI patients in the construction industry. They identified 218 cases, and the main mechanism of injury was falls (49%). Almost half of all construction-related TBIs occurred in buildings under construction (48.2%). The peak of construction-related TBI incidents was just before noon; this peak was even more pronounced in younger workers (younger vs older than age 45 years). The authors argued that the specific sleep cycle of younger workers may lead them to feel more tired in the late morning. In addition, peaks in TBI occurred in July and August and then in October, hypothesized as the busiest months for construction in Ontario.

Janicak[10] examined fatalities from construction-related TBI. Inspection data carried out by the US Occupational Safety and Health Administration on work-related fatalities from 1994 to 1996 were reviewed. Workplace TBI fatalities represented 27% of all work-related fatalities (876 of 3202 cases), of which 39% were related to the construction industry. Falls represented the main mechanism of injury in construction-related TBI (69% of cases) and the subcategory of heavy construction was related to the most workplace TBI deaths. These data are consistent with that of Colantonio et al.[9] More recently, Konda et al[11] also reviewed cases of fatal construction-related TBIs. Data obtained from the Bureau of Labor Statistics Census of Fatal Occupational Injuries from 2003 to 2010 showed an annual rate of fatal construction-related TBI of 2.6 per 100,000 full-time equivalent workers. They found that 25% of deaths related to construction work were due to TBI. Also, 24% of work-related fatal TBIs were found in the construction industry. The main mechanism of injury was falls. Older workers (>65 years) were at higher risk of death than younger workers.

Most of the literature is based on databases not permitting the analysis of clinically relevant data such as clinical status on arrival, need for surgery, complications, and neurological outcome. To our knowledge, no study to date has described workplace TBI using workers' stay and course in hospital. There is also no study on their clinical neurological outcome other than survival and death. We believe that examining the in-hospital course of workplace TBI patients would provide insight into their condition and possibly lead to identification of preventable risk factors.

A better understanding of TBI is justified on other factors. For instance, Pagulayan et al[12] found that TBI patients report decreased quality of life as well as a plateau in improvement around 6 months after the injury. Moreover, Langlois et al[13] report that TBI leads to approximately 235,000 hospital admissions yearly in the United States and that the estimated yearly cost, including acute and chronic medical care and lost productivity, is approximately $60 billion. In addition, Wrona[14] found that 31.3% of TBI patients end up with permanent disability, and this greatly reduces their ability to return to work. Finally, work-related TBI was found to account for more than one-fifth (22%) of all occupational fatalities in the United States by Tiesman et al.[15]

Taken together, these factors, as well as the lack of information on workplace TBI in the literature, justify further inquiry into the problem, in particular with the goal of characterizing and describing this group, which could increase knowledge on the consequences of TBI in workers.

Methods

The project was approved by the ethics review board of the McGill University Health Centre.

The Montreal General Hospital (MGH), part of the McGill University Health Center, is one of only three adult tertiary (level 1) trauma centers serving the Province of Québec, Canada, which has a population of almost eight million people. In a first step, the MGH Traumatic Brain Injury Database and the Trauma Registry Database (a province-wide registry[16]) were used to identify all patients admitted with a diagnosis of TBI between 2000 and 2014. The presence of a TBI, and whether work-related or not, is registered in the TBI Program database. Both the TBI database and the Trauma Registry Database are filled by personnel independent of the present study. There is also a systematic validation between the two databases every year. A TBI is considered work-related if the injury had occurred at the workplace and/or the injured worker was performing work duties. Patients were excluded if the TBI was not work-related, if there was no TBI (wrongly coded), and if their charts were incomplete or missing. A TBI diagnosis was retained when confirmed in the chart by a physician (either a neurosurgeon or a rehabilitation medicine physiatrist specializing in TBI). The diagnostic criteria for a mild TBI are those recommended by the World Health Organization Task Force on mild TBI.[17] The TBI could be the main diagnosis of admission or a secondary diagnosis (e.g. in the case of a polytrauma). Patients were also excluded if they had been admitted to an outside facility before their admission to the MGH (missing data on acute phase); however, patients initially seen in emergency departments (EDs) at outside facilities and quickly transferred to the MGH were included.

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We then conducted a medical record review (paper chart, electronic medical records, and radiological data) and retrieved the following data: demographic data (age, gender), workplace and injury information (mechanism of injury), clinical status on arrival (Glasgow Coma Scale [GCS]), computed tomography (CT) head scan results, in-hospital course, status on discharge, and timing of injury (using arrival in ED.

We analyzed the data using IBM SPSS Statistics (version 23) software to obtain descriptive statistics such as means and proportions.

Results

The databases identified 318 possible cases of work-related TBI. Of these, 285 cases met our inclusion criteria and these constituted our patient sample (Fig. 1 shows details on the excluded cases).

Demographic Data

The average age was 43.62 years (range, 16-76 years). The male-to-female ratio was 18:1, with 94.7% (270) of patients being male. Level of education was available only for 185 (65%) cases. Of these, 7.6% (14) had an elementary level of education (0-6 years of schooling), 57.3% (106) a high school level (7-11 years) education, 24.3% (45) a college or professional degree level (12-13 years), and 10.8% (20) had a university level (14 or more years).

Health Information

Information about medical history was available for 281 of 285 cases. Of these, 50.9% (143) reported having current or a history of medical disease or condition; the most common were: 16% (45) cardiovascular disease, 7.8% (22) psychiatric illness. and 9.3 % (26) drug or alcohol abuse. Oral anticoagulation or antiplatelet medication was used by 7.4% (21) of the patients at the time of their injury.

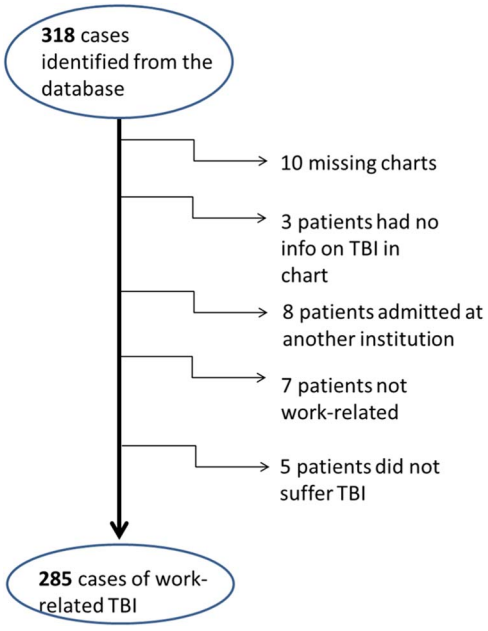

Figure 1: *Excluded cases*

Table 1: Distribution of industry/work types among patients

Industry/work type	Number of patients	Frequency (%)
Construction/trades	96	42.5
Vehicle driver/operator	32	14.2
Retail/sales	26	11.5
Manufacturing	16	7.1
City worker*	14	6.2
Mechanic	9	4.0
Electrician	7	3.1
Forestry	4	1.8
Office worker	3	1.3
Teaching	3	1.3
Others	16	7.1
Total	226	100

*City workers included city maintenance workers, police, and firefighters.

Work Environment and Mechanism of Injury

The type of industry or work involved was available in 226 cases (79.2%) (Table 1). Among these, the most common occupation was in construction and trades (42.5%), followed by vehicle drivers and operators (14.2%). The mechanism by which the head trauma occurred was clearly documented in 259 cases (90.8%) (Table 2). Most injuries were caused by falls (166 cases, 64.1%, with 123 falling from an elevation), followed by motor vehicle crashes (46 cases, 17.8%). We also examined the distribution of injury mechanisms by type of industry (Table 3). Most construction workers were injured by falls (78%, 75 cases). There was information on helmet use in 28 cases (15%) whereas helmet use was not applicable in 100 cases (35.1%, as in the case of truck drivers, for example). Only eight patients were recorded as having worn a helmet at the time of their head injury. Toxicology screening for alcohol or drug use at the time of injury was recorded only in 119 cases (41.8%). Of these, only 15 tested positive, with benzodiazepines being the most common type of drug (6/15 cases).

Timing of Injury

Timing of the work-related TBI was clearly documented for 190 patients (66.6%) who were directly brought to the level 1

Table 2: Mechanism of injury

Mechanism	Number of patients	Frequency (%)
Falls	166	64.1
From elevation	123	
From own height	13	
From unknown elevation	30	
Motor vehicle crash	46	17.8
Falling object/projectile	41	15.8
Electrocution	3	1.2
Assault	3	1.2
Total	259	100

Motor vehicle crash

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Table 3: Industry vs mechanism

Industry/mechanism	Falls	Falling object/projectile	Motor vehicle crash	Electrocution	Assault	Unknown	Total
Construction/trades	75	18	3	0	0	0	96
Vehicle driver/operator	12	2	13	0	2	3	32
Retail/sales	14	3	7	0	0	2	26
Manufacturing	9	7	0	0	0	0	16
City worker*	2	2	10	0	0	0	14
Mechanic	4	2	1	0	0	2	9
Electrician	4	0	0	3	0	0	7
Forestry	3	1	0	0	0	0	4
Office worker	1	0	1	0	0	1	3
Teaching	2	1	0	0	0	0	3
Others	11	2	3	0	0	0	16

*City workers included city maintenance workers, police, and firefighters.

trauma center ED from the scene of the accident. This information was not retained for 95 patients (33.3%) however who were first brought to peripheral hospitals and subsequently transferred to the trauma hospital. Among the former, a peak of arrivals occurred at 10:00 a.m., followed by a smaller peak from 2:00 to 4:00 p.m. (Fig. 2). Work-related TBI occurred in an almost uniform distribution throughout the year, with the highest number occurring in August (34 cases, 11.4%) and the fewest in December (11 cases, 3.9%; Fig. 3).

Injury Information

All trauma patients who are assessed in the ED are given a value on the GCS. The GCS is a validated method to assess neurological status after a TBI.[18,19] In our sample, 219 patients presented with a GCS of 13-15 (76.8%), 22 patients with a GCS of 9-12 (7.7%), and 44 with a GCS of 3-8 (15.4%).

Imaging findings

All patients admitted with a work-related TBI underwent CT scan of the head. A total of 205 patients had abnormal findings (71.9%), whereas 80 patients had no traumatic intracranial findings (28.1%). Of those with an abnormal CT scan, a skull fracture was found in 133 (64.9%), traumatic subarachnoid hemorrhage in 110 (53.7%), subdural hemorrhage in 109 (53.2%), brain contusions in 116 (56.6%), and epidural hemorrhage in 33 patients (16.1%). In fact, 150 patients had more than one finding on their CT scan (73.2% of those with findings).

Associated Injuries

TBI patients had other injuries in 72.6% of cases (207 patients). Amongst them, 50.7% had orthopedic injuries (105 cases), 31.4% intrathoracic injuries (65 cases), 30.9% maxillofacial injuries (64 cases), 27.1% spine injuries (56 cases), 18.4% ophthalmological injuries (38 cases), and 8.7 % intra-abdominal injuries (18 cases).

Treatment Required

One hundred cases (35.1%) required intubation as part of treatment of their injuries. Forty (14%) patients required cranial surgery, whereas 42 (14.7%) required intracranial insertion of a pressure-recording device (either an extra ventricular drain or a Codman intraparenchymal monitor) to monitor their intracranial pressure post-injury.

Hospital Course

The average total length of hospitalisation was of 13.77 days, with a median of 7 days (range, 1-146 days). The average length of stay in the intensive care unit was of 4.86 days, with a median of 1 day (range, 0-76 days). We found that 35.4% of patients suffered at least one complication during their admission (101 patients). Excluding death as a complication, the most common complications included infection in 59 patients and thrombosis in 19 patients. Twenty-three patients died during their hospitalization (8.1% of all patients).

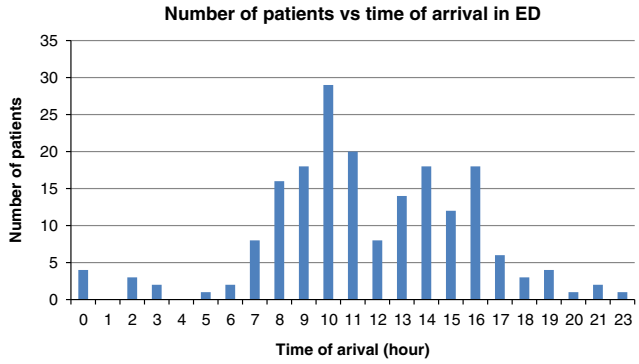

Figure 2: Time of arrival to the MGH ED

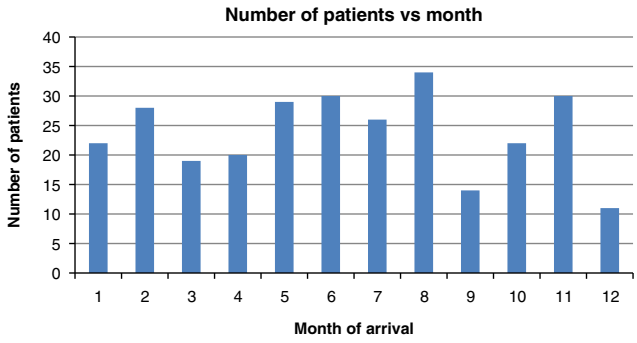

Figure 3: Month of arrival to the MGH ED

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Table 4: Extended GOSE results

Score	Status	Number of patients	Frequency (%)
1	Death	23	8.7
2	Vegetative state	0	0
3	Lower severe disability	3	1.1
4	Upper severe disability	24	9.1
5	Lower moderate disability	80	30.3
6	Upper moderate disability	122	46.2
7	Lower good recovery	12	4.5
8	Upper good recovery	0	0
Total	-	264	100

Partially reproduced from Wilson et al.[20]

Outcome

The TBI Program team members perform a structured interview on every patient at the time of discharge to determine the Extended Glasgow Outcome Scale (GOSE) score.[20,21] Although the GOSE is usually assessed at 3, 6, and 12 months after injury, patients in our series were assessed only before discharge (Table 4). GOSE information was available for 264 patients (92.6%) and showed that 12 patients had already reached a good recovery on discharge (score, 7; 4.5%); 202 patients still had moderate disability on discharge (scores, 5 and 6; 76.5%) and 27 patients still had severe disability (scores, 3 and 4; 10.2%). Finally, more than half of the patients were discharged home without any professional help (52.6%, 150 patients), whereas 25 patients were discharged home with outpatient rehabilitation (8.8%) and 75 patients were transferred to an inpatient rehabilitation centre (26.3%; see Table 5 for more detailed results).

Discussion

Our report is the first to examine clinically relevant variables among patients with work-related TBI. Patients were middle-aged men, with a high school level of education, and the largest percentage worked in a heavy industry, such as construction. Fall was the most frequent cause of the injury. A majority presented to the ED with a good neurological status. Their hospital stay lasted a median of about 1 week and, for most, did not require surgical intervention. Close to three of four patients had a CT scan of the head showing a skull fracture and/or a brain contusion. Once discharged from the hospital, patients were most likely to return home. However, more than one-third of the patients required continued rehabilitation services after discharge and 1 in 12 died of their injuries. Finally, one-third also suffered from at least one medical complication during their hospitalization.

Table 5: Destination on discharge

Discharge location	Number of patients	Frequency (%)
Home	150	52.6
Home with outpatient rehabilitation	25	8.8
Inpatient rehabilitation	75	26.3
Transfer to other hospital*	11	3.9
Long-term care facility	1	0.4
Death	23	8.1
Total	285	100

*On another acute care ward.

Intuitively, one would think that younger, less-experienced workers would tend to suffer more injuries, especially given that studies have shown that older workers generally have a better understanding of safety and perform more safely.[22,23] One study[4] indeed found decreasing rates of work-related TBI with increasing age. Our patient population age, however, was more consistent with data previously reported in many studies, with a high incidence of TBI in older workers.[5,6,8,24,25] This suggests that fatal falls in older workers could be related to decreased musculoskeletal coordination and strength.[26] The very high male:female ratio found in our sample is comparable to other studies,[5] basically reflecting the gender ratio in heavy industries in Canada.[27]

Although 16% reported cardiovascular disease, 7.4% reported the use of anticoagulant or antiplatelet medication, an important factor in TBI outcome.[28] This suggests that our sample population was relatively healthy, an implicit prerequisite for working, particularly in physically demanding jobs.[29] Reported mental health problems in this study and in others[5] suggested a low prevalence, at least in comparison with non–work-related TBI populations.[5] Toxicological screening was inconsistently performed and poorly recorded and therefore could be unreliable. Nevertheless, the reported prevalence of use was consistent with that in a recent report.[30]

Working in construction, driving a vehicle, and being an operator were the most common occupations in our sample. This distribution is similar to what other authors reported.[8,11,25] Falling objects and projectiles were also frequent causes of injuries. Unfortunately, in the medical record, data were largely missing as to the wearing of a protective helmet.

More than three-quarters of injured workers presented with a GCS score compatible with a mild head injury (76.8%), which is consistent with data from large epidemiological studies on TBI from all causes.[1] Given that most non–work-related TBIs are caused by falls and motor vehicle crashes,[8] the consistency of neurological state between workers and all patients affected by TBI is not surprising.

The GCS threshold at which endotracheal intubation is usually considered necessary for airway protection is a score of 8 or lower.[31] Although 44 patients (15.4%) presented with a GCS of 8 or lower, 100 patients required intubation for reasons other than surgery purposes. This can be explained by multiple factors. Combativeness is a major indication for intubation in trauma patients as reported by Sise et al, who reviewed 1000 intubations in the context of trauma.[32] Other reasons include trauma to the chest leading to hypoxia and hypoventilation, airway obstruction, or hemorrhagic shock.[32] In fact, almost three-quarters of our patients had concomitant injuries other than to the head, the most common type being orthopedic injuries. Others have also found a high rate of concomitant injuries in TBI. Leong et al reported that 78% of TBI patients in their cohort had associated extracranial injuries.[33] Leitgeb et al, who studied moderate and severe TBI patients only, reported a rate of associated injuries of 47.5%.[34]

A majority of our patients had abnormal findings on CT scan of the head as expected, because only patients with abnormal findings are referred to the neurosurgical team. The patients with a negative

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CT scan of the head who were seen by the TBI Program team were admitted because of significant TBI symptomatology or concomitant injuries. The most common finding on CT scan was a skull fracture, followed by brain contusions. Kica and Rosenman examined work-related skull fractures in injured Michigan workers.[35] Fractures occurred mostly in the construction and manufacturing industries. A relatively small percentage (14%) of our patients required a surgical intervention, which is lower than the 23.8% (70 cases of 294) reported by Heyer and Franklin.[25] This difference may be due to the significant advances in TBI care and trauma care in general that have occurred over the past 20 years. In Québec alone, since the establishment of a regionalized trauma care system in 1993, a reduction of overall mortality from trauma was observed going from 52% in 1992 through 1993 to 18% by 1997 through 1998.[36]

The length of stay in our sample (measured as an average) mirrors that reported by Kim et al,[5] but given its wide range (1-146 days), a better figure is the median estimated at 7 days. This number is closer to the mean of 6.8 days of hospital stay of work-related TBI patients reported by Heyer and Franklin[25] or the 7.5 days found by Salem et al.[37] Prevalence and nature of complications (infections and deep venous thrombosis) were similar to those reported in previous studies.[38-40] Most patients had a relatively positive clinical evolution. Nevertheless, a death rate of 8.1%, even if lower than in another similar population (11.3%),[5] is still very high.

Our study had limitations. First, there was poor documentation of certain variables in the medical charts. Second, we did not have access to longer term follow-up data, such as functional outcome at 6 and 12 months. Nevertheless, our overall results allow us to identify areas for improvement in safety and safety culture. The first target should be to reduce the incidence of work-related falls. Different measures have been proposed by Konda et al,[7] including safer work environment (e.g. railing, better lightning, even floors) and workers' behavioral changes (e.g. physical fitness, vision check-up). One measure that could lead to more protection during a fall and from falling objects is the wearing of a helmet; unfortunately, we could not document that observation adequately, but we suggest it should be a primary variable to collect. Finally, our study has also confirmed that the most common industry in which work-related TBI occur is the construction industry, as indicated by Konda et al.[11] We agree with Janicak[10] that this industry should therefore be specifically targeted by measures to reduce work-related TBI.

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Statement of Authorship

MP elaborated the project, collected the data, analyzed the data, and prepared the manuscript. CI-R elaborated the project, helped with the data analysis, supervised MP, and critically reviewed the manuscript. JM elaborated the project, supervised MP, critically reviewed the manuscript, and prepared the manuscript for submission and publication. All three authors reviewed the final submitted version of the manuscript.

Disclosures

The authors do not have anything to disclose.

References

1. Bruns J Jr, Hauser WA. The epidemiology of traumatic brain injury: a review. Epilepsia. 2003;44:2-10.
2. O'Connor C, Colantonio A, Polatajko H. Long term symptoms and limitations of activity of people with traumatic brain injury: a ten-year follow-up. Psychol Rep. 2005;97:169-79.
3. Hagan PE, Montgomery JF, O'Reilly JT. Accident prevention manual essentials. Itasca, IL: National Safety Council; 2014.
4. Kraus JF, Fife D. Incidence, external causes, and outcomes of work-related brain injuries in males. J Occup Med. 1985;27:757-60.
5. Kim H, Colantonio A, Chipman M. Traumatic brain injury occurring at work. NeuroRehab. 2006;21:269-78.
6. Coleman VP. Occupational head injury accidents in Great Britain. J Occup Accid. 1986;8:161-72.
7. Konda S, Reichard A, Tiesman H, Hendricks S. Nonfatal work-related traumatic brain injurys treated in US hospital emergency departments, 1998-2007. Inj Prev. 2015;57:245-53.
8. Chang VC, Guerriero EN, Colantonio A. Epidemiology of work-related traumatic brain injury: a systematic review. Am J Ind Med. 2015;58:353-77.
9. Colantonio A, McVittie D, Lewko J, Yin J. Traumatic brain injuries in the construction industry. Brain Inj. 2009;23:873-8.
10. Janicak CA. An examination of occupational fatalities involving impact-related head injuries in the construction industry. J Occup Environ Med. 1998;40:347-50.
11. Konda S, Tiesman H, Reichard AR. Fatal brain injuries in the construction industry, 2003-2010. Am J Ind Med. 2016;59:212-20.
12. Pagulayan KF, Temkin NR, Machamer J, Dikmen SS. A longitudinal study of health-related quality of life after traumatic brain injury. Arch Phys Med Rehabil. 2006;87:611-8.
13. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. J Head Trauma Rehabil. 2006;21:375-8.
14. Wrona RM. Disability and return to work outcomes after traumatic brain injury: results from the Washington State Industrial Insurance Fund. Disabil Rehabil. 2010;32:650-5.
15. Tiesman HM, Konda S, Bell JL. The epidemiology of fatal occupational traumatic brain injury in the U.S. Am J Prev Med. 2011;41:61-7.
16. Moore L, Lavoie A, Sirois MJ, Amini R, Belcaid A, Sampalis JS. Evaluating trauma center process performance in an integrated trauma system with registry data. J Emerg Trauma Shock. 2013;6:95-105.
17. Carroll LJ, Cassidy JD, Holm L, Kraus J, Coronado VG. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. J Rehab Med. 2004:(Suppl. 43): 113-25.
18. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2:81-4.
19. Teasdale G, Maas A, Lecky F, Manley G, Stocchetti N, Murray G. The Glasgow Coma Scale at 40 years: standing the test of time. Lancet Neurol. 2014;13:844-54.
20. Wilson JTL, Pettigrew LEL, Teasdale GM. Structured interviews for the Glasgow Outcome Scale and the Extended Glasgow Outcome Scale: Guidelines for Their Use. J Neurotrauma. 1998;15:573-85.
21. Wilson JT, Slieker FJ, Legrand V, Murray G, Stocchetti N, Maas AI. Observer variation in the assessment of outcome in traumatic brain injury: experience from a multicenter, international randomized clinical trial. Neurosurgery. 2007;61:123-8.
22. Siu OL, Phillips DR, Leung TW. Age differences in safety attitudes and safety performance in Hong Kong construction workers. J Safety Res. 2003;34:199-205.

23. Gyekye SA, Salminen S. Age and workers' perceptions of workplace safety: a comparative study. Int J Aging Hum Dev. 2009;68: 171-84.
24. Kristman VL, Côté P, Hogg-Johnson S, et al. The burden of work disability associated with mild traumatic brain injury in Ontario compensated workers: a prospective cohort study. Open Occup Health Saf J. 2010;2:1-8.
25. Heyer NJ, Franklin GM. Work-related traumatic brain injury in Washington State, 1988 through 1990. Am J Public Health. 1994;84:1106-9.
26. Agnew J, Suruda AJ. Age and fatal work-related falls: short note. Hum Factors. 1993;35:731-6.
27. Statistics Canada. 2006, Census Topic-based tabulations. Occupation - National Occupational Classification for Statistics 2006. Available at: http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/tbt/Rp-eng.cfm?LANG=E&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=0&GID=0&GK=0&GRP=1&PID=92104&PRID=0&PTYPE=88971,97154&S=0&SHOWALL=0&SUB=743&Temporal=2006&THEME=74&VID=0&VNAMEE=&VNAMEF=.
28. Mina AA, Knipfer JF, Park DY, Bair HA, Howells GA, Bendick PJ. Intracranial complications of preinjury anticoagulation in trauma patients with head injury. J Trauma. 2002;53:668-72.
29. Kirkeleit J, Riise T, Bjørge T, Christiani DC. The healthy worker effect in cancer incidence studies. Am J Epidemiol. 2013;177:1218-24.
30. Bush DM, Lipari RN. Substance use and substance use disorder by industry. SAMHSA. April 16 2015. Available at: http://www.samhsa.gov/data/sites/default/files/report_1959/ShortReport-1959.pdf.
31. American College of Surgeons Committee on Trauma. Advanced trauma life support for doctors. Student course manual, 8th ed. Chicago, IL: American College of Surgeons; 2008.
32. Sise MJ, Shackford SR, Sise CB, et al. Early intubation in the management of trauma patients: indications and outcomes in 1,000 consecutive patients. J Trauma. 2009;66:32-9.
33. Leong BK, Mazlan M, Abd Rahim RB, Ganesan D. Concomitant injuries and its influence on functional outcome after traumatic brain injury. Disabil Rehabil. 2013;35:1546-51.
34. Leitgeb J, Mauritz W, Brazinova A, Majdan M, Wilbacher I. Impact of concomitant injuries on outcomes after traumatic brain injury. Arch Orthop Trauma Surg. 2013;133:659-68.
35. Kica J, Rosenman KD. Surveillance for work-related skull fractures in Michigan. J Safety Res. 2014;51:49-56.
36. Sampalis JS, Denis R, Lavoie A, et al. Trauma care regionalization: a process-outcome evaluation. J Trauma. 1999;46:565-79.
37. Salem AM, Jaumally BA, Bayanzay K, Khoury K, Torkaman A. Traumatic brain injuries from work accidents: a retrospective study. Occup Med (Lond). 2013;63:358-60.
38. Schirmer-Mikalsen K, Vik A, Gisvold SE, Skandsen T, Hynne H, Klepstad P. Severe head injury: control of physiological variables, organ failure and complications in the intensive care unit. Acta Anaesthesiol Scand. 2007;51:1194-201.
39. Rincón-Ferrari MD, Flores-Cordero JM, Leal-Noval SR, et al. Impact of ventilator-associated pneumonia in patients with severe head injury. J Trauma. 2004;57:1234-40.
40. Cifu DX, Kaelin DL, Wall BE. Deep venous thrombosis: incidence on admission to a brain injury rehabilitation program. Arch Phys Med Rehabil. 1996;77:1182-5.

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