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Demographic profile and extent of healthcare resource utilisation of patients with severe traumatic brain injury: still a major public health problem

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INTRODUCTION Trauma is the fifth principal cause of death in Singapore, with traumatic brain injury (TBI) being the leading specific subordinate cause.

METHODS This study was an eight-year retrospective review of the demographic profiles of patients with severe TBI who were admitted to the neurointensive care unit (NICU) of the National Neuroscience Institute at Tan Tock Seng Hospital, Singapore, between 2004 and 2011.

RESULTS A total of 780 TBI patients were admitted during the study period; 365 (46.8%) patients sustained severe TBI (i.e. Glasgow Coma Scale score ≤ 8), with the majority (75.3%) being male. The ages of patients with severe TBI ranged from 14–93 years, with a bimodal preponderance in young adults (i.e. 21–40 years) and elderly persons (i.e. > 60 years). Motor vehicle accidents (48.8%) and falls (42.5%) were the main mechanisms of injury. Invasive line monitoring was frequently employed; invasive arterial blood pressure monitoring and central venous pressure monitoring were used in 81.6% and 60.0% of the patients, respectively, while intracranial pressure (ICP) measurement was required in 47.4% of the patients. The use of tiered therapy to control ICP (e.g. sedation, osmotherapy, cerebrospinal fluid drainage, moderate hyperventilation and barbiturate-induced coma) converged with international practices.

CONCLUSION The high-risk groups for severe TBI were young adults and elderly persons involved in motor vehicle accidents and falls, respectively. In the NICU, the care of patients with severe TBI requires heavy utilisation of resources. The healthcare burden of these patients extends beyond the acute critical care phase.

Keywords: demographics, healthcare utilisation, traumatic brain injury

INTRODUCTION

Severe traumatic brain injury (TBI) is a major health and socioeconomic problem globally.[1,2] TBI can be defined as a trauma-induced physiologic disruption or insult to the brain from an external mechanical force. Outcomes of TBI are diverse and can include physical, cognitive and social problems, with the majority of patients facing significant mortality and morbidity.

Country-based estimates of TBI incidence range from 108–332 new hospitalised cases per 100,000 population/year; differences in reported incidences may be due to variations in the definition of TBI.[3] In the United States, TBI accounts for approximately 40% of all deaths from acute injuries and approximately 200,000 victims of TBI require hospitalised care annually.[4] In Singapore, 'external causes of morbidity and mortality' (ICD10: V01-Y89) is the fifth principal cause of death,[5] with TBI being the leading specific subordinate cause. It is difficult to ascertain the full socioeconomic cost of TBI, but any financial estimate should include the cost of life-saving neurosurgical treatment and/or neurocritical care in the acute phase, other ongoing medical expenses (e.g. ambulatory and rehabilitation care), and the loss of potential income for the patient and caregiver.[4,6] In other words, TBI is a major public health concern. The objective of this study was to delineate the demographic profile of patients with severe TBI in the Singapore context, since this information has major implications in the management of TBI patients as well as the allocation and utilisation of scarce local healthcare resources. Such information would also be useful for devising prevention programmes in the local community. Importantly, the present study also highlights the impact of falls on the elderly.

METHODS

This retrospective study was approved by the Institutional Review Board of the National Healthcare Group, Singapore. The data of patients who were admitted to the neurointensive care unit (NICU) at the National Neuroscience Institute, Tan Tock Seng Hospital, Singapore, between 2004 and 2011 was obtained from a prospectively maintained TBI database. The data of patients with severe TBI was subsequently extracted for analysis. Patients who had a Glasgow Coma Scale (GCS) score of ≤ 8 following nonsurgical resuscitation (i.e. airway management, haemodynamic and volume support, electrolyte correction, and osmotic therapy) were considered to have severe TBI.

Data on patient demographics, the mechanism of injury leading to severe TBI, and the types of monitoring and treatment administered to reduce increased intracranial pressure (ICP) was collected and analysed. The data on the mechanism of injury was obtained from patient records from the emergency department,

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Table I. Traumatic brain injury (TBI) patients, classified by severity (n = 780).

Severity of TBI*	No. (%)
Mild	232 (29.7)
Moderate	183 (23.5)
Severe	365 (46.8)

*Based on the Glasgow Coma Scale (GCS) score, mild: GCS 13–15; moderate: GCS 9–12; severe: GCS ≤ 8.

Table II. Demographic data of severe traumatic brain injury patients (n = 365).

Variable	No. (%)
Gender	
Male	275 (75.3)
Female	90 (24.7)
Ethnicity	
Chinese	244 (66.8)
Malay	44 (12.1)
Indian/Bangladeshi	53 (14.5)
Others	24 (6.6)
Age group (yr)	
0–20	26 (7.1)
21–40	123 (33.7)
41–60	100 (27.4)
> 60	116 (31.8)
Nationality	
Singaporean	288 (78.9)
Non-Singaporean	77 (21.1)

Table III. Details of the injury sustained by patients with severe traumatic brain injury (n = 365).

Variable	No. (%)
Source of referral	
Emergency department	344 (94.2)
Regional local hospital	8 (2.2)
Neighbouring country	13 (3.6)
Location of accident	
Home	78 (21.4)
Street/highway	174 (47.7)
Work/school	14 (3.8)
Others	99 (27.1)
Mechanism of injury	
Motor vehicle accident	178 (48.8)
Fall from height ≥ 2 m	27 (7.4)
Fall from height < 2 m	128 (35.1)
Assault	18 (4.9)
Sports/recreation-related	1 (0.3)
Others	13 (3.6)

ambulance pre-hospital care records and/or the patient's history as reported by family members or witnesses. Death/mortality was evaluated based on the assessment of the patients' condition (i.e. dead or alive) at the end of their hospital stay. High-risk activities were defined as activities that resulted in high-impact falls (i.e. from a height ≥ 2 m), motor vehicle accidents (MVAs),

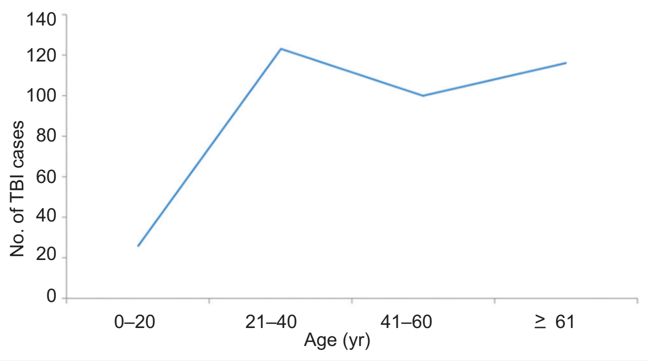

Fig. 1 Line graph shows the bimodal age distribution of the patients with severe traumatic brain injury (TBI; n = 365).

activities involving assaults and sports-related activities. Elderly patients were defined as patients aged > 60 years.

Statistical analysis was performed using IBM SPSS Statistics version 20.0 for Windows (IBM Corp, Armonk, NY, USA). Chi-square test was used to evaluate the association between age group/gender and the outcome of patients with severe TBI. Logistic regression analysis predicting falls from a height < 2 m and high-risk activities was used to estimate the odds ratios, 95% confidence intervals (CIs) and p-values of the predictor variables, after controlling for age group, gender and nationality. All statistical tests were two-sided and a p-value < 0.05 was considered to be statistically significant.

RESULTS

Over the eight-year period from January 2004 to December 2011, 780 patients were admitted to the NICU with TBI of various levels of severity (Table I). On average, there were about 110 cases of TBI per year. Among the 780 patients, only 365 (46.8%) patients were admitted for severe TBI; the remainder (n = 415, 53.2%) had mild-to-moderate TBI.

The demographic data of the 365 patients with severe TBI is summarised in Table II. The mean age of these 365 patients was 48.6 ± 20.3 (range 14–93) years. A bimodal age distribution was observed, with the two peaks occurring at the age groups of 21–40 years and > 60 years (Fig. 1). There was a male preponderance (75.3%). 21.1% of the 365 patients were non-Singaporeans who were largely from countries around the region such as Bangladesh, China, India, Indonesia, Malaysia, Myanmar, the Philippines and Thailand.

Details of the injuries, such as the mechanism of injury, are presented in Table III. The chief cause of severe TBI was MVAs (48.8%), followed by falls from a height < 2 m (35.1%); collectively, these two causes accounted for 83.8% of cases of severe TBI. When severe TBI was analysed according to the patients' age groups, more than half (57.3%, n = 102) of the 178 MVAs occurred among those aged ≤ 40 years (Table IV). The majority (67.2%, n = 86) of the 128 falls from a height < 2 m occurred among those aged > 60 years. When analysed according to the patients' nationalities, non-Singaporeans were found to be more likely to suffer from severe TBI due to high-risk activities, with MVAs and falls from a height ≥ 2 m being the top two causes (Table V).

Table IV. Mechanism of injury among the patients with severe traumatic brain injury, according to age group (n = 365).

Mechanism of injury	Age group (yr)			
	≤ 20 (n = 26)	21–40 (n = 123)	41–60 (n = 100)	> 60 (n = 116)
Motor vehicle accident	19 (73.1)	83 (67.5)	52 (52.0)	24 (20.7)
Fall from height ≥ 2 m	3 (11.5)	13 (10.6)	11 (11.0)	0
Fall from height < 2 m	2 (7.7)	11 (8.9)	29 (29.0)	86 (74.1)
Assault	1 (3.8)	11 (8.9)	4 (4.0)	2 (1.7)
Others	1 (3.8)	5 (4.1)	4 (4.0)	4 (3.4)

Data presented as no. (%).

Table V. Mechanism of injury among the patients with severe traumatic brain injury, according to nationality (n = 365).

Mechanism of injury	No. (%)	
	Singaporean (n = 288)	Non-Singaporean (n = 77)
Motor vehicle accident	129 (44.8)	49 (63.6)
Fall from height ≥ 2 m	16 (5.6)	11 (14.3)
Fall from height < 2 m	118 (41.0)	10 (13.0)
Assault	13 (4.5)	5 (6.5)
Others	12 (4.2)	2 (2.6)

Table VI. Results of logistic regression predicting the mechanism of injury among patients with severe traumatic brain injury.

Variable	Crude OR (95% CI)	p-value
Fall from height < 2 m		
Age group (yr)		
0–20	1	
21–40	1.179 (0.245–5.664)	0.837
41–60	4.901 (1.087–22.094)	0.039
> 60	34.400 (7.667–154.350)	< 0.0001
High-risk injury*		
Age group (yr)		
0–20	1	
21–40	0.848 (0.177–4.082)	0.837
41–60	0.204 (0.045–0.920)	0.039
> 60	0.029 (0.006–0.130)	< 0.0001
Gender		
Female	1	
Male	1.700 (1.045–2.766)	0.033
Nationality		
Singaporean	1	
Non-Singaporean	4.651 (2.299–9.409)	< 0.0001

*All other mechanisms of injury except fall from a height < 2 m. CI: confidence interval; OR: odds ratio

Table VII. Comparison of the outcomes of severe traumatic brain injury, according to age group and gender.

Variable	No. of patients (n = 365)	Mean injury severity score	Mean presenting GCS score	No. of deaths (%)
Age group (yr)				
≤ 60	249	26.50 ± 10.33	5.048 ± 2.013	91 (36.5)
> 60	116	25.71 ± 9.14	4.733 ± 1.839	89 (76.7)*
Gender				
Male	275	25.96 ± 10.34	4.865 ± 1.956	128 (46.5)
Female	90	27.11 ± 8.72	5.200 ± 1.973	52 (57.8)†

*p < 0.0001. †p = 0.069. GCS: Glasgow Coma Scale

Age was found to be an independent predictor of severe TBI after a fall from a height < 2 m. Elderly patients (i.e. aged > 60 years) were approximately 34 times more likely to sustain severe TBI after a fall from a height < 2 m, as compared to patients in the younger age groups (95% CI 7.667–154.350, p < 0.0001) (Table VI). Conversely, the risk of severe TBI due to high-risk mechanisms of injury (e.g. MVAs, assaults and falls from a height ≥ 2 m) among elderly patients was low, at merely 0.029 times that of the younger age groups (95% CI 0.006–0.130, p ≤ 0.0001). Male and non-Singaporean patients were found to be 1.700 (95% CI 1.045–2.766, p = 0.033) and 4.651 (95% CI 2.299–9.409, p < 0.0001) times as likely to suffer from severe TBI arising from high-risk mechanisms of injury, respectively.

A comparison of the outcomes of severe TBI between the age groups revealed that the elderly were more likely to experience a poorer outcome as compared to patients aged ≤ 60 years (Table VII). The elderly presented with a worse GCS score (4.733 ± 1.839 vs. 5.048 ± 2.013) than patients aged ≤ 60 years, even though the elderly were found to suffer from less severe injuries based on the Injury Severity Score (ISS) (25.71 ± 9.14 vs. 26.50 ± 10.33). In addition, there was a greater proportion of deaths among the elderly patients as compared to patients aged ≤ 60 years (76.7% vs. 36.5%, p < 0.0001). Patients with severe TBI were found to spend a mean duration of 6.0 ± 8.99 days in the NICU; the mean total duration of inpatient hospitalisation was 27.8 ± 55.00 days (Table VIII).

The monitoring modalities that were applied to the 365 patients with severe TBI are summarised in Table IX. Invasive line monitoring was the most frequently employed modality among patients with severe TBI: arterial blood pressure monitoring was used in 298 (81.6%) patients, while central venous pressure monitoring was used in 219 (60.0%) patients. ICP measurement was required in 173 (47.4%) patients. Continuous end-tidal capnography was used in 12.9% of the patients to supplement measurement of arterial carbon dioxide partial pressure ($PaCO_2$). Tiered therapy such as sedation, osmotherapy with mannitol, cerebrospinal fluid drainage, moderate hyperventilation, barbiturate-induced coma and decompressive craniectomy were used for treatment of raised ICP (Table X). Other common therapies used in the NICU, in the context of severe TBI, include

Table VIII. Length of stay of patients with severe traumatic brain injury.

Variable	Mean ± standard deviation	Range
Duration of stay in NICU (day)	6.0 ± 8.99	1–88
Duration of hospital stay (day)	27.8 ± 55.00	1–618
Singaporean	29.1 ± 59.98	1–618
Non-Singaporean	23.2 ± 29.60	1–147

NICU: neurointensive care unit

Table IX. Monitoring modalities applied to patients with severe traumatic brain injury (n = 365).

Monitoring modality	No. (%)
Intracranial pressure measurement	173 (47.4)
Invasive line monitoring	
Arterial line	298 (81.6)
Central venous pressure line	219 (60.0)
End-tidal capnography	47 (12.9)

Table X. Incidence of tiered therapy used for raised intracranial pressure (ICP) (n = 365).

Therapy	No. (%)
Sedation	205 (56.2)
Barbiturate-induced coma	64 (17.5)
Moderate hyperventilation*	9 (2.5)
Osmotherapy	64 (17.5)
Induced hypothermia	95 (26.0)
Muscle paralysis	9 (2.5)
Tracheostomy	84 (23.0)
Vasopressor/ionotropic support	93 (25.5)
Blood transfusion	233 (63.8)
Decompressive craniectomy with ICP monitor insertion	87 (23.8)
External ventricular drain/cerebrospinal fluid drainage	18 (4.9)
Burr hole/craniotomy and evacuation of extradural/subdural haemorrhage	20 (5.5)

*Defined as $PaCO_2$ 26–30 mmHg.

blood transfusions (63.8%), induced hypothermia (26.0%), vasopressors (25.5%) and tracheostomies (23.0%). The total in-hospital mortality was 49.3% (n = 180) for patients with severe TBI. Among the 87 patients who underwent decompressive craniectomy, 31 (35.6%) died during their hospital stay.

DISCUSSION

In the present study, 415 (53.2%) of the 780 patients with TBI who were admitted to the NICU had mild-to-moderate TBI. This indicates that a substantive proportion of the NICU workload was dedicated to patients who were not suffering from severe TBI. Patients with non-severe TBI still require management in the NICU, especially those who are at risk of acute deterioration, such as elderly patients.[7,8] Greater attention to this group of patients is warranted and the close neurological monitoring offered by the NICU plays an important role in the management of TBI in such cases.

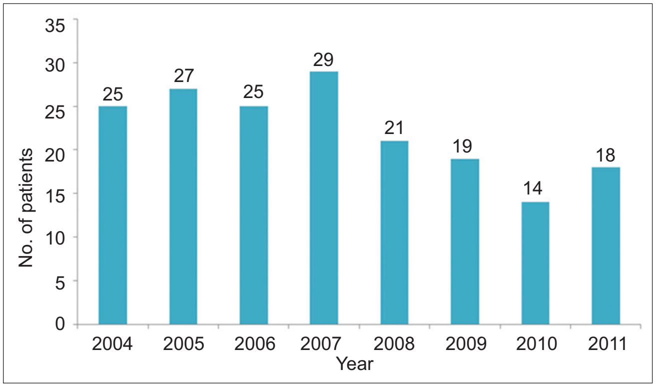

Fig. 2 Bar graph shows the annual number of patients admitted to the neurointensive care unit of the National Neuroscience Institute at Tan Tock Seng Hospital, Singapore, with traumatic brain injury caused by motor vehicular accidents (2004–2011).

The incidence of severe TBI had a bimodal age distribution in this study; the first peak was observed in the young adult age group (i.e. 21–40 years), while the second peak was observed in the elderly age group (i.e. > 60 years). Overall, male patients were found to be approximately 3–4 times more likely to sustain severe TBI than female patients (75.3% vs. 24.7%). The difference in the incidence of severe TBI among the different age groups and genders may demonstrate differing predisposing factors.[9,10] This is evidenced partly by the fact that young males are substantially overrepresented in the severe TBI cases resulting from high-risk activities such as MVAs and assaults. Conversely, the elderly formed the bulk of severe TBI cases that resulted from low-height/impact falls (i.e. falls from a height < 2 m).

A previous local study reported a decrease in MVA-related severe TBI cases admitted to the NICU of the National Neuroscience Institute at Tan Tock Seng Hospital, Singapore, in the years leading up to 2004.[11] The present study appears to show that the downward trend at the same NICU continued during the years of 2005–2011 (Fig. 2). This decrease in MVA-related severe TBI admissions, which is congruent with the general decrease in MVA incidence nationally, could be related to a reduction in head trauma resulting from strict legislation and enforcement of personal road safety measures (including, but not limited to, the need to wear helmet and seat belts).[12] Additionally, the 2010 opening of a new public-sector hospital, Khoo Teck Puat Hospital, in northern Singapore could have reduced the number of admissions to our unit.

Severe TBI being common among young adults is a major public health concern, as this would result in a reduced number of productive life years due to death or disability, inflicting high costs on society. The observation that a large majority of such injuries and fatalities occur among males in their economic prime is also reflected in many other studies.[13,14]

Depending on the underlying mechanism of trauma, 70% of patients with TBI may have associated polytrauma, fractures, cardiopulmonary or visceral injuries, spinal cord injuries, peripheral nerve injuries and limb amputations.[15] These conditions may aggravate neurodisability due to craniocerebral trauma. Survivors of severe TBI have a marked reduction in life expectancy, dying two times faster than the general population. Furthermore, survivors of severe TBI face the need for prolonged care and rehabilitation, and have consequent long-term physical, cognitive and psychological disorders that affect their independence, relationships and employment.[16,17]

Similar to most developed countries, Singapore has an ageing population that has given rise to a new cohort of elderly persons who sustain significant TBI from fairly low-height falls (i.e. falls from a height < 2 m). The bimodal age distribution observed in the present study, with peaks occurring at the young adult (aged 21–40 years) and elderly age groups, has also been reported in other studies.[3,6,18] In many high-income countries, comprehensive traffic safety legislation, preventive measures and educational campaigns have limited the rise in the incidence of transport-related TBI.[11] However, the incidence of TBI caused by low-height falls is increasing as the population ages, resulting in a rise in the median age of the TBI population. In this study, the elderly formed a large part of the severe TBI cohort, with most (74.1%) of the severe TBI cases caused by falls from a height < 2 m. Compared to their younger counterparts, elderly persons have a greater fall propensity due to multifactorial causes. These causes include: (a) intrinsic patient factors, such as cognitive/mental or musculoskeletal disabilities, cardiac arrhythmias and postural hypotension, and visual, proprioceptive or balance impairments; (b) extrinsic environmental factors, such as poor lighting or glare, furniture hazards and uneven flooring; and (c) social/behavioural factors, such as living alone and poor safety awareness.[19] Consequently, there may be a pattern shift in the types of TBI seen, with focal intraparenchymal or subdural haematomas (resulting from low-height falls among older patients) gaining prominence over diffuse injuries (resulting from high-velocity accidents among younger patients).

Although many of the severe TBI cases among elderly patients in this study were caused by low-height falls with less severe ISS, these patients presented with a much lower GCS score and higher mortality outcome as compared to patients from the younger age group (Table VII). It has long been recognised that elderly patients are more likely to develop subdural haematoma, particularly from minor trauma. Generalised cerebral atrophy and increased venous fragility of the bridging veins, both of which are associated with ageing, are the major predisposing factors.[20] In addition, elderly persons are often frail and suffer from multiple medical comorbidities such as poorly controlled systemic hypertension; the use of antiplatelet or anticoagulant medications is a risk factor for haematoma expansion.[7] Age has been cited to be a significant risk factor for poorer outcome in TBI and the prognosis worsens for patients aged > 60 years; this is related to elderly patients having poorer neuronal reserves due to cerebrovascular disease and dementia.[15] It is this combination of factors that prompts surgeons to place elderly patients in the intensive care unit (ICU) for heightened monitoring, as these patients are more likely to deteriorate abruptly.

We also found that the home was the second most common (21.4%) location of accidents that resulted in severe TBI (Table III). Most (74.1%) of the severe TBI cases that involved patients aged > 60 years resulted from low-height falls occurring in the most benign of locations, such as the home, where a large proportion of the elderly are alone for most of the day (Table IV). Recent government-led initiatives, such as the Enhancement for Active Seniors scheme (which provides a financial subsidy for the installation of elderly-friendly safety fixtures at home) and the Lift Improvement and Facilities Enhancement for the elderly project (which carries out selective upgrading of facilities in one-room rental flats, where many elderly citizens live alone) may prove beneficial in reducing falls and fall-related trauma such as closed head injuries and hip fractures.

As of December 2012, the foreign workforce in Singapore, who are mainly from Southeast Asian countries, the Indian subcontinent and China, amounts to 1.27 million.[21] Many of these workers are involved in industrial, building construction and shipbuilding/repair activities, which are inherently high-risk. In the present study, 21.1% of the patients with severe TBI were non-Singaporean (i.e. foreign workers). Foreign workers were more likely to suffer from severe TBI that was associated with high-risk activities, with MVAs and falls from a height ≥ 2 m forming the top two causes (Table V). To address the high incidence of severe TBI among the foreign workers, workplace safety needs to be improved, including emphasising the importance of personal protective measures such as the use of helmets and safety harnesses among construction workers.[11] In the last decade, falls from a height have been the leading contributor to workplace fatalities in Singapore.[22] Regulatory and enforcement frameworks, such as the Singapore Ministry of Manpower's Programme-based Engagement initiative, are part of the strategic effort to reduce the incidence of work-related accidents. While workplace injuries are on a downward trend,[23] they remain high despite ongoing efforts.

The vast majority of the patients with severe TBI had invasive arterial line monitoring in the NICU. The use of arterial line monitoring is essential, as tight regulation of the patient's mean arterial blood pressure (MAP) is necessary in the setting of severe TBI. In addition, arterial line monitoring allows the derivation of cerebral perfusion pressure (i.e. MAP – ICP) and provides access for arterial blood samples to be taken. Central venous access and pressure monitoring was also widely employed among the patients with severe TBI. Thus, invasive line monitoring can be regarded as part of the standard monitoring of salvageable patients with severe TBI;[24] it is possible that the utility of end-tidal carbon dioxide monitoring needs greater recognition and application in our unit.

The incidence of the use of tiered therapy (e.g. sedation, osmotherapy with mannitol, cerebrospinal fluid drainage, moderate hyperventilation and barbiturate-induced coma) in the present study to control ICP converged with international practices.[25] The majority (56.2%) of the patients with severe TBI required hypnotic pharmacotherapy (i.e. the use of midazolam, propofol and/or fentanyl) for sedation in our NICU. Sedation is employed mainly for control of ICP, facilitation of mechanical ventilation or endotracheal tube tolerance, or blood pressure control. Patients with severe TBI who have a low post-resuscitation

GCS score may not require further sedation. Hyperventilation should only be used as an acute temporising measure in the context of life-threatening and refractory intracranial hypertension, due to the potential for exacerbating cerebral ischaemia;[24] the judicious use of moderate hyperventilation, defined as $PaCO_2$ 26–30 mmHg, was reserved for only a small proportion (< 3%) of the patients in the present study.

The benefit of decompressive craniectomy was recently brought into question.[26] The use of early craniectomy in diffuse traumatic brain injury (DECRA) effectively decreases ICP and the length of stay in the ICU, but increases the proportion of patients with an unfavourable functional outcome (i.e. worse scores on the Extended Glasgow Outcome Scale) as compared to patients who receive standard care. In response to the perceived limitations of the DECRA trial,[27] the Randomised Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of Intra-Cranial Pressure study is currently in progress.

To conclude, TBI has often been described as a silent epidemic. The results of the present study are consistent with other reports that document the greater frequency of MVA-related TBI among younger individuals and fall-related TBI among the elderly. The second peak in the incidence of severe TBI was from patients aged > 60 years; this group of patients, which accounted for 31.8% of all patients with severe TBI in the present study, were also found to have poorer functional outcome even though they had seemingly less severe ISS at presentation. Locally, fall-related TBI among the elderly may be expected to further increase in view of Singapore’s ageing population.

TBI is a prime contributor to the global burden of disease and disability. It continues to be an exigent domain of healthcare, particularly in developed, high-income countries. The management of TBI precedes and goes beyond the NICU, hence should be viewed as a continuum from pre-hospital emergency systems to community-based rehabilitation care. Prevention requires a multipronged, tailored, preventive strategy that involves educating at-risk populations in society (e.g. the young, elderly and persons from high-risk occupational groups) as well as relevant legislation, engagement and enforcement.

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