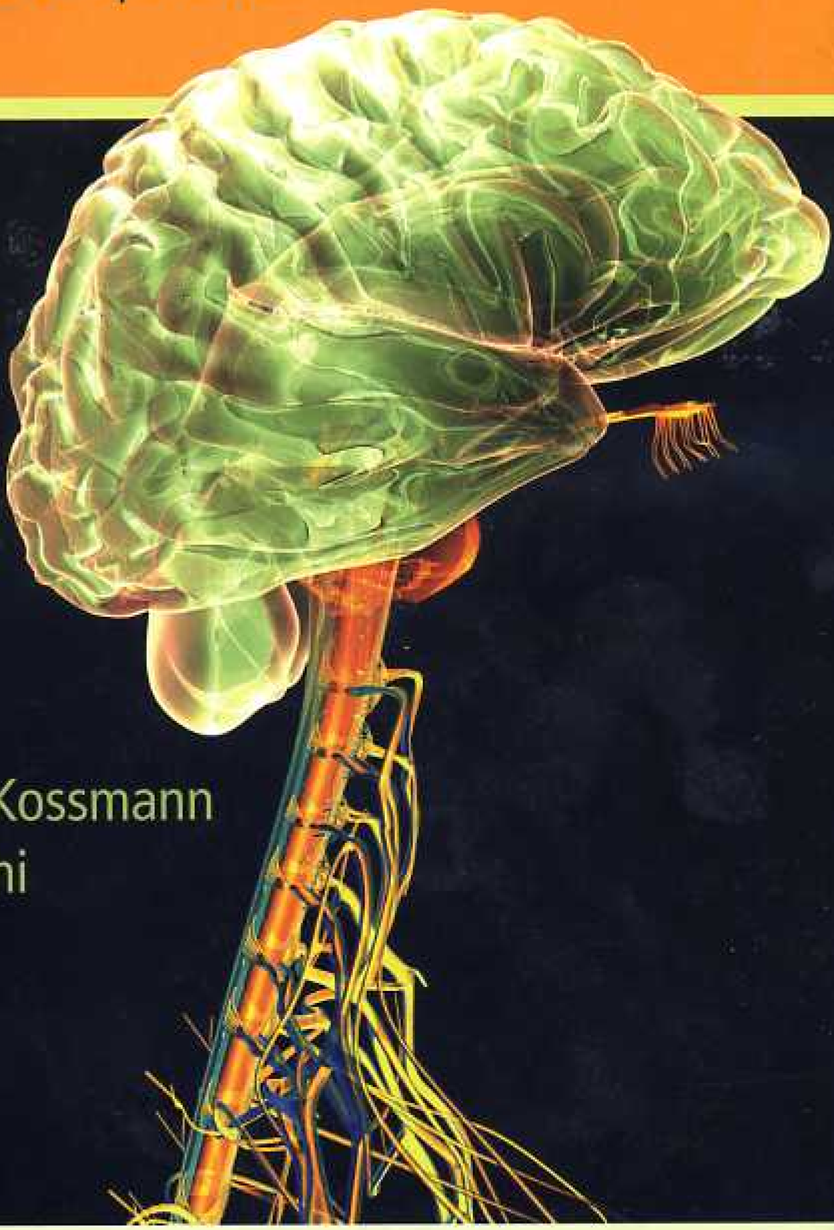
Traumatic Brain and Spinal Cord Injury

Challenges and Developments



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CAMBRIDGE Medicine

Chapter 2

Neurotrauma: an emerging epidemic in low- and middle-income countries

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Of "all the aches and pains the flesh is heir to", head injury seems to be the most devastating one. It profoundly impacts the life of the sufferer as well as the family members and society in general, causing significant economic burden. Worldwide, the incidence of neurotrauma has been ratcheting up and it has now become an international public health problem. Neurotrauma has been dubbed a "silent epidemic" affecting both the developed as well as the developing nations [1].

Introduction

With sociodemographic and epidemiological transition, injuries have become a major health concern in every country around the world, in both high-income and low- and middle-income countries. The impact of globalization, urbanization and industrialization has resulted in changing environments and lifestyles affecting the day to day life of individuals. With decline of communicable and infectious diseases, all low- and middle-income countries (LMICs) of the world are facing a major epidemic of injuries, primarily road traffic injuries. Official reports indicate primarily deaths, which are only the tip of the iceberg. For every death, nearly 30–50 are hospitalized and many more seek care from emergency centers all around the world. Injuries also leave significant numbers of persons with physical and psychosocial disabilities along with phenomenal socioeconomic impact on the affected individuals and families.

According to the World Health Organization's Global Burden of Disease (GBD) study estimates, injuries result in deaths of nearly 5 million persons every year globally [2]. Among them, unintentional injuries resulted in 3.9 million deaths during 2004. Unintentional injuries contributed for nearly 7% of total deaths and 9% of disability-adjusted life-years (DALYs). Injuries are a leading cause of death at 15 to 44 years and primarily include road traffic injuries (RTIs), falls and other unintentional injury causes such as mechanical (workplace) and sports injuries. The burden of injuries is also significant in LMICS of the world. As per the WHO, nearly 90% of unintentional injury deaths and 94% of DALYs were in LMICs in 2004. The disability-adjusted life-years due to unintentional injuries like road traffic injuries and falls were 17.5% and 12.2%, respectively.

As per GBD estimates, the rate of unintentional injuries in 2004 was estimated to be 61 per 100000 population per year. The rates were highest in the southeast Asia region (80 per 100000 population per year) and lowest in the American region. As per the findings of the GBD study, road traffic injuries (33%), falls (11%) and drowning (10%) contributed nearly half the deaths [2]. Road traffic injuries are one of the leading causes of injuries, resulting in the deaths of nearly 1.3 million people every year with a mortality rate of 20 per 100000 population [3]. The death rates are nearly double in LMICs (65 vs. 35 per 100000) and the rate for the DALYs is more than 3 times (2398 vs. 774 per 100000), meaning that more people are injured, and a greater number suffer from non-fatal health outcomes as a result of injuries in LMICs.

Traumatic brain injuries

Among all traumas, injury to the brain and spinal cord is a major cause of injuries, resulting in deaths and disabilities. Traumatic brain injury (TBI) is a major public health problem resulting in a large number of deaths, significant impairments and huge

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socioeconomic losses. Due to the acute nature of the event and its impact on the most vital part of the body, the outcomes are most significant. There is a common perception even in the scientific community that TBIs are an event and initial treatment and a brief spell of rehabilitation are necessary. It is essential to note that TBIs can be permanent due to irreversible neuropathological alterations, may need life-long rehabilitation and require supervision and care. The mortality is high and life expectancy can be shortened due to TBIs. The complications and sequelae include headache, seizures, neuroendocrine problems, sexual dysfunction, bladder and bowel problems, and several others [4].

Comprehensive understanding of TBIs is possible with good data on incidence, mortality, case fatality, prevalence, disability rate or outcomes. Due to difficulties in measurement and lack of data from around the world, the precise epidemiological characteristics of persons with TBI are unclear, especially in LMICs. Since TBIs are often not recognized, they are referred to as a silent, hidden and unrecognized epidemic. LMICs due to large populations and deficient healthcare services along with an absence of safety policies and programs are facing a major epidemic of TBIs and its consequences.

Problems with the epidemiological studies of neurotrauma

A major problem with the study of neurotrauma is the lack of a standardized case definition of neurotrauma in population-based assessments. Several terms have been used interchangeably such as head injury, brain injury, traumatic brain injury (TBI) and acquired brain injury. The Center for Disease Control has laid down the case definition of TBI which should be followed in epidemiological studies and public health surveillance [5].

For surveillance systems using data from clinical records, a case of TBI (craniocerebral trauma) is defined as an occurrence of injury to the head that is documented in a medical record, with one or more of the following conditions attributed to head injury: observed or self-reported decreased level of consciousness, amnesia, skull fracture, objective neurological or neuropsychological abnormality, or diagnosed intracranial lesion; or as an occurrence of death resulting from trauma, with head injury listed on the death certificate, autopsy report, or medical examiner's report in the sequence of conditions that resulted in death.

Injuries to the head may arise from blunt or penetrating trauma or from acceleration–deceleration forces.

Decreased level of consciousness refers to partial or complete loss of consciousness. This includes states described as obtundation, stupor or coma.

Amnesia may include loss of memory of events immediately preceding the injury (retrograde amnesia), of the injury event itself and of events subsequent to the injury (post-traumatic amnesia).

Neurological abnormalities are determined from neurological examination. Examples include abnormalities of motor function, sensory function or reflexes; abnormalities of speech (aphasia or dysphasia); or seizures acutely following head trauma. Neuropsychological abnormalities are determined from mental status and neuropsychological examinations. Examples include disorders of mental status (such as disorientation, agitation or confusion) and other changes in cognition, behavior or personality.

Examples of diagnosed intracranial lesions include traumatic intracranial hematomas or hemorrhage (epidural, subdural, subarachnoid or intracerebral), cerebral contusions or lacerations or penetrating cerebral injuries (e.g. gunshot wounds). The diagnosis of such intracranial lesions is usually confirmed with a computed tomography (CT) or magnetic resonance imaging (MRI) brain scan or by other neurodiagnostic procedures.

The clinical definition of TBI also excludes the following:

- lacerations or contusions of the face, eye, ear or scalp, without other criteria listed above
- fractures of facial bones, without other criteria listed above
- birth trauma
- primary anoxic, inflammatory, infectious, toxic or metabolic encephalopathies which are not complications of head trauma
- neoplasms
- brain infarction (ischemic stroke) and intracranial hemorrhage (hemorrhagic stroke) without associated trauma.

Several difficulties and challenges are encountered in understanding the magnitude and characteristics of TBI in LMICs. Even in high-income centers (HICs), the burden, pattern and outcomes are difficult to comprehend due to methodological variations. As many countries, especially LMICs, do not have systematic hospital registration and reporting systems, the burden of TBIs is difficult to establish. Hospital discharge diagnosis does not adequately capture the type and nature of TBIs, and such reporting systems are also lacking in the majority of LMICs. Injury surveillance programs or neurotrauma registries, as it exists in some of the HICs, are just beginning to emerge in some countries. The death certificates issued by hospital authorities may not mention TBI as the cause of death, especially when patients die after a prolonged hospital stay. The ICD-10 classification systems are also not extensively used and hence the proportion of TBIs in hospital settings is unclear. LMICs also face extreme shortages of diagnostic and imaging facilities along with an acute shortage of trained and skilled manpower. Consequently, many of the minor TBIs are missed and only seen when sequelae manifest and predominate. Further, many TBIs that occur in the context of polytrauma are under-reported or grouped in different categories. Most importantly, different practices are followed in different countries for diagnosis, defining severity, assessing disabilities and measuring complications, and hence data from LMICs are difficult to compare.

Burden of TBIs

The precise numbers of people with a TBI are not clearly known due to lack of systematic data in many countries. However, it is estimated that TBIs affect more than 10 million people leading to mortality or hospitalization [6]. A report from the World Health Organization predicts that TBIs are likely to become the leading cause of mortality worldwide by 2020 [7]. Globally in 1990, one estimate shows TBI causing deaths or hospital admissions in 9 500000 cases [8]. This is probably a very modest estimate as this does not include minor TBIs. Data from a few of the countries falling in both HIC and LMIC categories are given below as examples that serve to illustrate the burden of TBIs.

Even in HICs, TBIs are a major public health problem (Table 2.1). Earlier reports from the USA indicate that TBIs were the cause of nearly 50000 deaths annually, nearly a third of all injury-related deaths. There were 230000 hospitalizations for non-fatal TBI with an estimated 80000 resulting in long-term disability [9].

TBIs in low- and middle-income countries

Hyder *et al.*, in a recent review on TBIs, used the data from the GBD study to estimate the global burden, using the reported outcomes of "fractured skull" and "intracranial injury" [10]. The review revealed that the TBI-related RTIs were significantly higher in Latin American and sub-Saharan African countries. India, one of the Asian countries, also has a huge problem of TBIs with 160/100000. The incidence rate in Sao Paulo, Brazil, is estimated to be 360/100000 population per year [11], while a hospital-based study from Hong Kong reported TBI rates of 924/100000 population [12]. In South Africa, the reported incidence rate of TBIs was found to be 316/100000 population in Johannesburg, while in Yemen the prevalence was found to be 219/100000 based on a 2-year study of TBIs. Some detailed perspectives on TBIs from some individual countries are highlighted in subsequent sections of this report.

TBI in Nigeria and other African countries

Africa is facing wars of two different kinds with similar mortality: road traffic injuries and civil wars. One study based on a questionnaire shows that the mortality rate at the site of trauma was 20–30%, during transportation 7–20% and 2–10% on hospital admission [13]. More than 50% of deaths due to head injuries occur even before hospital admission. The report highlights several factors which might contribute to the rising mortality in the context of RTIs such as road users' attitudes, poor traffic management, the design and state of the roads and poor pre-hospital services.

Motorcycles, known as "okada" in Nigeria, are the most popular commercial transport vehicles in Africa. The rider can negotiate the traffic congestion and poor road networks better. A recent study prospectively focused on patients with motorcycle injuries (MCI) excluding ocular injuries presenting to the surgical emergency room of the University of Ilorin Teaching Hospital (UITH), Nigeria, between August 2004 and July 2005 [14]. During the study period, 412 road traffic accident victims presented to the casualty, of which 112 were due to MCI (27.2%). The majority of the MCI

Table 2.1. Incidence of TBIs in high-income countries of the world

Sl. No	Authors	Place	Incidence rate (100 000 per year)	Mortality rate (100 000 per year)	Case fatality (%)
1	Kraus *et al.*	USA	180	30.0	5.9
2	Nestvold *et al.*	Norway	236	5.5	3.3
3	Annegers *et al.*	USA	193	20.0	–
4	Tiret *et al.*	France	281	–	2.2
5	Gururaj *et al.*	India	160	18.0	9.6
6	Chiu *et al.*	Taiwan	182	19.0	10.6
7	Jennett B	England	270	9.0	–
8	Anderson *et al.*		546		
9	Kleiven *et al.*	Sweden	259		
10	Santos *et al.*	Portugal	137		
11	Servadei *et al.*	Italy	205		
12	Steudel *et al.*	Germany	337		

patients were students (20.5%), either as passengers or pedestrians on the journey to and from schools, while traders (17.9%), artisans (17%) and commercial cyclists (11.6%) were the other main groups of the riders. Interestingly, none of the riders was wearing a helmet at the time of crash. Sixty-three percent of MCI patients sustained head injuries and 70.5% limb injuries involving multiple injuries. Previous reports suggested an incidence of MCI in Nigeria in the region of 10.3% to 14.1% [15, 16]. This study reporting the figure of 27.2% shows the incidence of MCI to have doubled over the last 10 years.

A cross-sectional study in Kenya shows that road traffic injuries are on the rise and most road traffic casualties are among the young population and poor backgrounds [17]. The study also highlighted the fact that most centers in the country were ill prepared for the management of RTI: only 40.8% of recipient facilities could cope. Fifty-one percent of the patients reached facilities within 30 minutes of the crash and medical care was provided to 66.2% of patients.

Neurotrauma in Pakistan

An epidemiological study by Ali Raja and colleagues portrays the pattern of neurotrauma in Pakistan [18]. The study collated data from patients with head injuries from different neurosurgical units in Pakistan between July 1995 and June 1999. The number of patients admitted with head trauma in the study totaled 260 000 over the 4-year period. The most common reason for the head injury was RTI (52.8%). RTIs were commonly due to vehicles colliding with pedestrians, vehicle to vehicle collisions and falls from moving vehicles and two-wheelers. Similarly, falls from height were commonly seen to be due to falls from roofs, balcony tops, stairs and trees. Assault was commonly with sharp and blunt objects. Occupational and sports injuries were also common in Pakistan.

Neurotrauma in India

Over the last 50 years, the total number of registered motor vehicles on Indian roads has gone up by 237 times, as shown in Table 2.3. Among them, motorized two-wheelers registered growth by nearly 2000 times. This exponential rise reflects rapid urbanization, industrialization, economic expansion and affordability of motor vehicles in India. It is estimated that nearly 1 million people die of injuries every year, with 30 million hospitalizations. Among these deaths, nearly half could be due to brain injuries [19].

Gururaj and colleagues undertook an epidemiological study as early as 1992–1993 on neurotrauma at National Institute of Mental Health and Neurosciences (NIMHANS) in the Indian city of Bangalore [20]. This study estimated the incidence rate to be 160/100 000 per year (Table 2.1). The mortality rate was 18 per 100 000 per year during this period. This study included only those treated by the selected hospitals. Overall, the TBIs were contributory for 21% of all injuries. In the epidemiological study at NIMHANS, RTIs were found to be the most common cause of TBI (62%), followed by falls (22%), assaults (10%) and fall of objects (4%). Among total deaths (262) the above causes explained 68%, 22%, 5.5% and 3%, respectively. An earlier study reported from India showed the incidence of RTI causing TBI to be 49% which has clearly gone up as evident from the NIMHANS epidemiological study.

Odero *et al.*, in a review of RTIs, observed that in developing nations, pedestrians, motorcyclists and bicyclists together are most at risk of sustaining head injuries [21]. Compared to an earlier study reported from India, the incidence has increased considerably [22]. The analysis of 1784 RTIs in the Bangalore study and recent data in 2005 has shown that the most vulnerable groups including pedestrians, motorcycle riders and pillions and bicyclists are killed and injured in greater numbers. Pedestrians are most likely to suffer as a result of crashes, especially involving heavy vehicles like trucks and buses. Collisions with pedestrians accounted for 29.5% of head injuries, while vehicular collisions contributed for 27% [19, 20]. The Indian experience in this context differs from that in the West, where motor vehicle occupants are at a greater risk compared to motorcyclists and bicyclists.

The major reasons for the increasing number of RTIs are several, with some important ones being greater exposure to motor vehicles, unsafe road conditions, poor design of national and state highways, non-use of helmets and seat belts, increasing consumption of alcohol, visibility issues, over-speeding and other traffic violations [19, 23]. Risk factor data on RTIs are just beginning to emerge, even though human factors are reported to be causative in the majority of road crashes by official agencies. A study reported from India enumerated the behavioral factors as follows: sudden crossing of the roads by the pedestrians without anticipation and observation (35.5%), speeding motorists (21%) and dangerous driving (18%) [20]. A variety of issues related to road conditions have been described: potholes, ditches, poor highway maintenance, inappropriate road humps and poor lighting. In total, road environment factors contributed to 10–15% of road traffic injuries. The problems with the motor vehicle itself were responsible for 44% head injuries in this study. Another major factor contributing to motorbike crashes in India is the increasing use of mobile phones while driving.

Falls are also a frequent cause of TBIs in India, especially among children and the elderly, and account for nearly one-quarter of deaths and hospitalizations [19]. In certain parts of India, war-related violence is increasing, for example Kashmir. In Kashmir, the incidence of ballistic trauma secondary to bullets, blasts and stabs has increased since 1990 subsequent to civil disturbance in the state [24]. A recent study done in Kashmir shows a steady increase of TBI patients: in 1996 the total number of TBI patients was 1629, while the figure went up to 3105 in 2003 [25]. In this study, assaults have been reported to cause TBI in 18.8%, firearm injuries in 0.8% and blast injuries in 3.8% of subjects. This underscores the rising political violence in the state of Kashmir. However, road traffic accidents are still the most common cause of TBI, accounting for 44.4% of cases [25].

Neurotrauma in Papua New Guinea

Neurotrauma explains 60% of all trauma deaths in Papua New Guinea and two-thirds of the deaths occur before the patient reaches hospital [26]. The epidemiological studies from the country found that the commonest causes of head injuries were assaults, motor vehicle accidents and falls [27]. In urban areas, motor vehicle crashes are common and occupants often travel unprotected and unrestrained in the back of open vehicles. In rural areas, falls from trees are an important cause of TBI. Coconuts falling on the head is another unique mechanism of TBI [28].

Neurotrauma in Vietnam

In Vietnam, traffic casualties are increasing at an estimated rate of 300% per year [29]. Vietnam has seen a huge increase in the number of motor vehicles where road transport networks are not prepared for the boom. The roads are narrow, meandering, often cobblestoned and filled with street vendors. Lack of helmet protection explains the rising number of deaths and head injuries involving bicycle and motorcycle accidents [30]. In a recent government report from Vietnam, 60 000 road accidents have been documented of which 85% were caused by "people's subjective sensibility", including 32% by speeding, 29% improper turning and passing and 11.3% drink driving. Lack of car parking space in the capital city of Hanoi compounds the problem further [29]. The case of Vietnam is also a classic example demonstrating that prevention programs yield results. With national helmet legislation, the number of serious head injuries and TBI deaths decreased considerably.

Neurotrauma in China

China, with a large population over 1.3 billion, has witnessed massive motorization in recent years. The bicycle is an important mode of transportation in China despite the increasing numbers of cars. One study has found the death rate due to TBI involving bicycle injuries to be 2.2 per 100 000 population, more than 7 times that in the USA [31]. TBIs accounted for 60% of the police-reported bicycling injuries and 17% of those treated in emergency rooms. In 79% of TBIs, the impact of the head with the concrete or asphalt road was a major cause. None of the patients had protective helmets at the time of accident. Zhao and Wang as early as 2001 reported the incidence of TBIs in China to be 55.4 per 100 000 population in the six big cities and 64.1 per 100 000 patients in the 21 rural areas, with a mortality rate of 6.3 per 100 000 population (male:female = 1.7:1.0) in the six cities and 9.7 (m:f = 2.5:1) in the rural areas [32]. The major causes of brain injury were vehicle accidents (31.7%), followed by assaults (23.8%), falls (21.8%), stumbles (15.4%) and others. The authors concluded that in the past decade, vehicle accidents have increased along with the increasing number of cars and motor bicycles. It was estimated that approximately 50 000 to 60 000 people die from vehicle accidents per year, with brain injuries contributing to 39% to 57% deaths and spinal cord injury about 10%. In a recent survey of 77 hospitals through standardized structured questionnaires in Eastern China over a 1-year period, TBIs were found to be the leading cause of deaths and hospitalizations [33]. Young males were affected most. Traffic accidents (60.9%), impacts to the head (13.4%) and falls (13.1%) were the leading causes of patients with TBI. One-third of the traffic-related TBI were among motorcyclists, 31% among pedestrians, and one-fifth among cyclists.

Neurotrauma in Taiwan

The incidence of neurotrauma is on the rise in Taiwan. A recent study from the Taiwanese city of Taipei estimates the incidence rate at 218 per 100 000 [34]. Another study describes the pattern of neurotrauma amongst the adolescents in rural and urban settings. Traffic injuries were the most common cause of head injury, and in both urban and rural areas motorcycle-related injury was the most common [35]. Chiu *et al.* (1997) collected data from 58 563 cases of TBI from 114 hospitals in Taiwan during the period July 1, 1988 to June 30, 1994 and observed that traffic accidents were the major cause of TBI (69.4%), followed by falls and assaults [36]. Motorcyclists were the most commonly affected group in TBIs. The study also reveals the effectiveness of helmet legislation and enforcement as seen by a significant reduction of TBI-related hospitalization, severity and fatality during this period of intervention.

Pediatric neurotrauma

TBIs among children are an important cause of concern in all countries. An international multicenter study of head injury in children examined head injuries among 0–15 year olds seen in emergency rooms and those hospitalized in the five countries Argentina, Brazil, France, Hong Kong and Spain [37]. Severe injuries accounted for 5%, while moderate and mild injuries were 39 % and 56%, respectively. Nearly two out of three children were boys and in younger age groups. A study from Nepal retrospectively examined pediatric head trauma and all children with head injury less than 16 years from April 2005 to March 2006 were included [38]. Falls from a height were the most common cause of injury in 28 out of a total of 43 patients (65.11%), followed by RTIs in 11 (25.6%). Mild head injuries defined by GCS 13–15 (65.11%) were most common. In urban areas of Nepal, RTIs such as vehicular crashes, motorcycle accidents and pedestrians hit by moving vehicles are common and in rural areas falls from a height are commoner.

A study done in Taiwan examined pediatric neurotrauma over an 8-year period and showed that traffic injury is the most common cause of neurotrauma (47.3%), followed by falls (40.3%) [39]. Of all the traffic injuries, motorcycle-related ones are the most common, followed by pedestrian and bicycle-related.

Cricket is a popular game in several southeast Asian countries and Africa. A prospective study undertaken in Srinagar, India, shows that pediatric TBI due to cricket ball impact is quite serious even if a plastic ball is used instead of a proper cricket ball [40]. In this study, 21 children out of 27 showed lesions on CT brain scan; of them six patients needed surgery (three for epidural hematoma, one for subdural hematoma, one for contusion and one for compound depressed fracture). Public awareness and appropriate safety precautions would prevent such incidents.

Prevalence of TBIs

Data on the prevalence of TBIs are totally lacking due to lack of data from healthcare institutions and the absence of population-based surveys. However, data from the Bangalore Urban–Rural Neuroepidemioloigcal survey conducted on a population of 102 500 from urban and rural Bangalore revealed the prevalence of TBIs to be 97/100000 [41]. The study showed the problem to be more prevalent in the rural population. Data from the USA and Europe reveal that the disabilities and sequelae from TBIs are significant and phenomenal, placing a huge burden on health services for both acute and long-term rehabilitation [42].

Age and gender

Injury reviews from all over the world, including the World Report on Road Traffic Injury Prevention (WHO 2004) and the World Report on Violence and Health (2002), reveal that men are affected much more than females, especially for road crashes and certain types of violence. As per GBD data, nearly 2.5 million deaths and over 87 million disability-adjusted life-years occurred among men [43]. Even among men, nearly half of unintentional injury deaths (47%) occurred in the age group 15–47 years, with similar observations for DALYs.

TBIs are predominantly a problem of the young and are seen in greater numbers in 15–44-year-olds. Two of the studies on TBIs in India reveal that the majority of subjects were in the 15–44 years range[19]. Similar observations have been made in other studies. With regard to falls, children and the elderly are involved in greater numbers and risk factors are different in both age groups. Interpersonal violence is seen more among the young and the above-mentioned studies reported that more than half were in the 15–44 years age group.

Due to differential exposures of males and females, men are affected in greater numbers in a ratio of 3:1. A major difference could be in the area of domestic violence and TBIs, with greater involvement of young women. The involvement of women in TBIs indicates greater hardship experienced by other family members.

External causes of TBIs

The commonest causes of TBIs around the world are RTIs, falls, violence, occupational injuries and sports-related injuries. Data from many parts of the world indicate that the majority (60%) are due to RTIs, 20–30% due to falls, 10% due to intentional injuries like violence, with another 10% due to a combination of work and sports-related injuries [44].

With RTIs increasing in numbers almost every day in all LMICs and with increasing motorization, RTI-related TBIs are expected to increase in the coming years. With current rates of change, RTIs are expected to be the third leading cause of mortality in the world by 2020 [43]. As per a recent review of the impact of TBIs, the highest rates of TBIs due to RTI are seen in Latin America and the Caribbean region with rates in sub-Saharan Africa not lagging far behind [10]. Countries like India and China have the highest rates of TBIs. According to data from several RTI studies in LMICs and as per the WHO, the vulnerable road users are predominantly pedestrians, two-wheeler riders and pillions and pedal cyclists. In sharp contrast to the situation in high-income countries, motor occupants are in smaller numbers. Available data from India are pooled in Tables 2.2 and 2.3. Recent data from the Bangalore Road Safety and Injury Prevention Programme in India reveal that the vulnerable road users account for nearly 80% of RTIs and collisions of these road users with heavy vehicles result in a greater number of TBIs with poor outcomes [19].

By being the second leading cause of TBIs, falls contribute nearly 20% of mortality. A bimodal distribution is seen, with children and the elderly being affected in larger numbers [10, 36]. Falls from high places, buildings, treetops and road-side sports areas are some predominant characteristics in LMICs. With the increase in the number of the elderly across the world, a greater number of fall injuries in this age group through falls from staircases and in homes is likely to contribute to a greater number of TBIs.

Violence has been a silent and hidden epidemic in the majority of the low- and middle-income countries.

Table 2.2. External causes of neurotrauma in Indian studies (%)

Year	Author	Traffic	Fall	Assault	Unknown	Others
1977	Kalyanaraman	45.4	35.6	11.8	1.5	5.7
1987	Natarajan *et al.*	44.0	19.0	30.0	–	9.0
1993	Bharathi *et al.*	49.1	23.6	23.4	–	3.9
1993	Gururaj *et al.*	61.6	22.5	10.6	1	4.3
1993	Sidhu *et al.*	45.1	11.5	9.6	–	37.5
2004	Thiruppathy SP and Muthukumar N	Most common mode of injury				
2008	Gururaj *et al.* [a]	46.0	9.0	17.0		2.0
2008	Yatto and Tabish	44.4	32.2	18.8		
2010	Gururaj *et al.* [a]	51.5	5.0	19.4	–	3.2

[a] From the injury surveillance programme.

Table 2.3. Road user categories in TBIs – Indian region (%)

Author	Pedestrian	Motorized two-wheelers	Bicyclists	Four-wheeler occupants	Other	Unknown
Mohan and Bawa, 1985	33	16	21	3	10	
Colohan ART *et al.*, 1989	20	22	1	25	–	32
Maheshwari, 1989	26	39	12	–	9	5
Gururaj *et al.*, 1993	31	35	10	20	–	4
Sidhu *et al.*, 1993	15	30	13	43	–	–
Sahdev P. *et al.*, 1994	33	40	6	4	–	17
Gururaj *et al.*, 1999	20	34	4	14	–	23
Jha *et al.* 2003	23	23	23	10	7	–
Varghese, 2003	35	18	25	1	–	–
Gururaj, 2004	26	43	8	7		
Verma and Tiwari, 2004	25	46	14	4	3	–
Dandona *et al.* 2008	6.4/100 persons/year	6.3/100 persons/year	5.1/100 persons/year			
Gururaj G *et al.*, 2008	52	37	3	5	3	
Gururaj G *et al.* 2010	24	58	4		2	

The precise magnitude of the problem is not known and it is estimated that 10–15% of TBIs are due to violence [43]. In sharp contrast to the high-income countries, violence in countries like India is due to the use of sharp and blunt routinely available objects and commonly due to interpersonal violence and violence against women, children and the elderly. In HICs, the pattern is commonly due to violence inflicted through weapons and firearms.

Role of alcohol in TBIs

Use of alcohol in developing countries is on the rise and drink driving, also known as "driving while impaired" (DWI) or "driving under the influence" (DUI), is becoming a major issue contributing to RTIs. In a study in New Delhi, an analysis of police records showed that 32% of the pedestrian fatalities, 40% of the motorized two-wheeler rider deaths and 30% of the bicyclists' deaths occurred between 6 pm and 6 am whereby alcohol intoxication was a major factor [23]. With increasing use of two-wheelers it is concerning to note that 29% of the two-wheeler victims were under the influence of alcohol [45]. It has been reported that 40% of the truck and matador drivers, 60% of the car drivers and 65% of the two-wheeler drivers were under the influence of alcohol at night. A series of studies undertaken by the WHO Collaborating Centre for Injury Prevention and Safety Promotion has revealed that the presence of alcohol in road crashes varies from 18% to 32% and is significantly higher in night-time crashes. Gururaj has observed that severe brain injuries, extensive body injuries, higher mortality rates, disabilities and increased duration of hospital stay have been reported in the alcohol group [46].

Risk factors in TBIs

Apart from age and gender, several other sociodemographic and environmental factors have been implicated in the etiology of TBIs. Lower levels of education, poor income groups, migrating families and workers in unsafe environments are known to predispose to the occurrence of TBIs. Several environmental factors like slippery floors, unsafe staircases and unsafe playgrounds are known to result in a greater number of fall-related TBIs.

Especially for RTIs, a number of human, environmental and vehicle factors are known to be linked with causation. The World Report on Road Traffic Injury Prevention outlines four categories of risk factors linked to exposure, crash severity, risk factors and outcome as causative factors for RTIs [44]. Apart from alcohol consumption, non-usage of helmets, seat belts and child restraints, non-adherence to traffic rules, over-speeding and overtaking are well-established risk factors, even in LMICs. Poor design and operation of roads and lack of pedestrian facilities result in greater numbers of RTIs. Vehicles with high speeding capacities and in unsafe condition also result in higher numbers of TBIs. Similarly, the World Report on Violence and Health outlines a number of predisposing and causative factors for violence, especially in LMICs.

Poor trauma care in both pre-hospital and hospital is a well-acknowledged contributor for poor outcomes following an injury [47, 48]. Some of the known factors like lack of first aid, improper referrals, lack of diagnostic and investigative facilities, unsafe transportation and others have been attributed to poor outcomes following TBIs.

Severity and nature of TBIs

The extent and nature of damage to the brain are primarily dependent on the nature of the impacting object and the speed of impact apart from the area of the brain damaged. Data in this regard are scant from LMICs and use of standard assessment procedures like an injury severity scale or the Glasgow Coma Scale is limited. Consolidated data from Europe indicate that most of the brain injuries are mild, with severe and moderate injuries being less than 10% each [49]. Despite differences in injury mechanisms and patterns, data available from LMICs show a similar trend in severity. Available studies indicate that the majority of brain injuries (50–60%) based on Glasgow Coma Scale scores are mild in nature. Severe brain injuries contribute 15–20 % of all TBIs and mortality is observed to be significantly higher in this group [19]. Wu *et al.* in a survey of 77 hospitals in China observed that the distribution of head injury severity based on Glasgow Coma Scale scores was mild in 62%, moderate in 18.1% and severe in 20% for all cases [33]. Traffic accidents resulted in severe injuries to the extent of 70.4%. Chiu *et al.* [36] in Taiwan in an analysis of 58 563 TBI patients noticed that the majority (79.5%) were mild in nature, 8.9% were moderate and 11.6% severe based on Glasgow Coma Scale scores. In the same study skull X-rays showed fractures in 14.6% cases, with the presence of intracranial hemorrhage in 28.6% of patients receiving CT scanning. Due to severe shortage of imaging facilities and trained manpower along with a lack of ICD coding mechanisms, the diagnosis of different types of TBIs is severely handicapped in many LMICs. In addition, high mortality is also seen among individuals with polytrauma in series of TBI patients.

Outcome following TBIs

Rehabilitation of brain-injured persons has not received much attention due to lack of facilities and skilled manpower in LMICs. With a decline of communicable and infectious diseases, disabilities due to injury-related TBIs are bound to increase in the coming years. In the USA, an estimated 43.3% of Americans have residual disability 1 year after hospitalization with TBI, with the most recent estimate indicating the prevalence of those living with disability following hospitalization with TBI being nearly 3.2 million [42]. In Europe, lack of data has been a limiting factor; however, studies indicate long periods of hospitalization, persistent consequences and life-long problems [49].

Data in this area are limited and scant due to lack of well-designed population-based epidemiological studies. In two of the longitudinal studies of TBI patients in Bangalore, India, it was observed that 15–20% of the patients had not recovered 12 months after brain injury [19]. The majority of the patients had difficulties in activities of daily living and also problems in memory, information processing, speech and other areas. A significant number were receiving care even at 24 months after injury, with all of them requiring support from their family members. Chiu *et al.* in Taiwan observed that outcome of TBI as determined by the Glasgow Outcome Scale was death (5.4%), vegetative state (0.9%), severe disability (2.6%), moderate disability (3.9%), and good recovery in the remaining 87.2% of cases [36]. In Eastern China, Wu *et al.* reported that, based on Glasgow Outcome Scale assessment, 10.8% died, 2.6% were in vegetative status, 2.2% had severe disability, 7.2% had moderate disability and 77.3% had good recovery [33]. Further, the authors also observed that the outcome depended on age, injury mechanism and initial Glasgow Coma Scale score. Rehabilitation facilities as seen in the West are lacking in LMICs and require urgent attention.

Economic impact

The fact that brain injuries are a significant drain on resources in growing economies in LMICs has not been realized by policy makers. Once again data in this area are not available from developing countries. Nevertheless, limited studies have pointed to the huge burden of neurotrauma as young productive people are affected significantly. The cost of neurotrauma can be direct or indirect. Direct costs include expenses towards transportation, pre-hospital and acute hospital care, rehabilitation and property damage along with any funeral expenses. Indirect costs are due to loss of productivity and income, loss of wages of family members, unmeasured time spent on rehabilitation and legal and compensation expenses, which are significant in settings where insurance coverage is non-existent or bare minimum.

In developing countries, RTIs alone are estimated to cost 1% of the gross national product, changing to 1.5% in countries in economic transition and to about 2% in HICs. Globally, RTIs cost over US $518 billion and over US $65 billion in LMICs [50]. Some of the studies have estimated the cost of management of brain-injured persons for a day to vary from INR 2000 to 3000 per hour. A population-based survey on the socioeconomic impact of road traffic injuries revealed that the hospitalization costs amounted to anywhere from INR 7300 to INR 29000 depending on the severity of injury and pattern of healthcare [51]. A 2-year follow-up study of brain-injured persons highlighted that families had to spend a huge amount of resources and had to sell their assets to manage the crisis [19]. As per estimates, it is known that a country like India alone loses resources to the tune of INR 55000 crores every year or 3% of GDP every year [52].

Prevention and control

Despite huge increases in the number of people with brain injuries efforts towards prevention have been extremely limited in LMICs. Recent experiences from around the world indicate that road traffic injuries and even falls can be reduced significantly with available knowledge. William Haddon, the first director of the National Traffic Safety Bureau in the USA, proposed a model for prevention of traffic injuries, which embodies the dynamic interaction of the three variables, human, vehicle and environment, in three sequential phases: pre-accident (prevention), accident and post-accident and this model is illustrated in Figure 2.1 [53]. The principles of Haddon's matrix apply to all injuries and have formed the basis of success in HICs. Considering the limitations of human behavior, it is now recommended that a systems approach focusing on safe people, safe roads and a safe environment is crucial for control of RTIs across the world. Clinicians all over the world should join forces to increase funding for neurotrauma research and to raise awareness of neurotrauma amongst the laity [54].

Several cost-effective and proven interventions like increasing helmet usage, reducing drinking and driving, use of seat belts and child restraints, strengthening

		Human	Vehicles and equipment	Environment
Pre-crash	Crash prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design and road layout Speed limits Pedestrian facilities
Crash	Injury prevention during crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash-protective design	Crash-protective road-side objects
Post-crash	Life-sustaining	First-aid skills Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Figure 2.1. The Haddon matrix.

pre-hospital and acute care practices, improved pedestrian safety and road engineering measures can significantly reduce the burden of TBIs related to RTIs. Without reinventing the wheel, these interventions need to be implemented through integrated and coordinated approaches.

With falls being a leading contributor to TBIs, the precise mechanisms of prevention needs to be understood with better research in low resource settings. However, some environmental and engineering measures are known to reduce the burden of falls [6]. Making homes, play site areas and workplaces safer along with improved parental and caregiver's supervision can help in reducing the number of fall-related TBIs. Similarly violence prevention needs to be given high importance in view of its increase in occurrence in LMICs.

Many of the good trauma care practices such as decreasing the time interval between burden of injury and reaching definitive hospital care, early availability of first aid, proper triaging and referral services, training of doctors and nurses in emergency care, improving facilities at all levels of healthcare systems, safe transportation of the injured and quality assurance of trauma systems can reduce deaths as well as negative outcome following TBIs [44, 55]. Comparative studies between India and the USA have revealed great disparities in emergency care, and cost-effective strategies are required for timely management of brain-injured persons [56].

In order to effectively implement cost-effective and proven interventions through the four Es of Education, Enforcement, Engineering and Emergency care a policy framework and strategic pathways are crucial in LMICs. Some of the pillars for prevention programs like intersectoral approaches, epidemiological surveillance, safe transfer of technology, advocacy, funding and strategic interventions are crucial to reduce the burden of neurotrauma. A high level of political commitment is an absolute necessity in these countries. Relevant public health policies based on multi-sectoral involvement forms the strong pillar for effective interventions.

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Cover illustration: a lateral view (right side) of the brain and the cervical spinal cord. **The brain and cervical spinal cord. Courtesy of Medical RF.com/Science Photo Library.**

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