Chapter 1

Epidemiology of Head Injury

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Introduction

Head injury is a major cause of morbidity and mortality in all age groups. Injury to the head can result in traumatic brain injury (TBI) of varying severity. TBI is common, with a self-reported lifetime prevalence of up to 40% in adults.[1] Currently, there is no effective treatment to reverse the effects of the primary brain injury sustained, and treatment is aimed at minimising the secondary brain injury that can occur due to the effects of ischaemia, hypoxia and raised intracranial pressure. This can occur immediately, within the following hours or days, or after a further head injury. An understanding of the epidemiology of head injury is essential for devising preventive measures, to plan population-based primary prevention strategies and to provide effective and timely treatment, including provision of rehabilitation facilities to those who have suffered a head injury. This information can then be used to improve TBI outcomes.

Definition and Classification of Traumatic Brain Injury

Whilst studying the epidemiology of TBI, it is important to realise that definitions, coding practices, inclusion criteria for patients and items of data collected have varied between studies. This has made it difficult to draw meaningful comparisons of incidence rates and risk factors between populations. TBI is usually considered an insult or trauma to the brain from an external mechanical force, leading to temporary or permanent impairments of physical, cognitive and psychosocial functions with an associated diminished or altered state of consciousness. The severity of TBI is usually classified according to the Glasgow Coma Scale (GCS) scores as mild (13–15), moderate (9–12) and severe (3–8). This classification may also be refined with data about pupillary response, age and CT findings, which further improves the prognostic and predictive value.[2,3] The International Classification of Diseases (ICD-10) codes for TBI are given in Table 1.1.

One of the problems of head injury research is case ascertainment. The majority of data collected will be from those who have presented to an accident and emergency (A & E) department, with subsequent admission to an observation or neurosurgical ward or a neurosurgical intensive care unit (Table 1.2). Following admission, they may not survive the injury or may be discharged home or to a rehabilitation facility or to long-term institutional care.

Burden of Traumatic Brain Injury

TBI is an important global public health problem. It is a major cause of disability. Survivors often suffer cognitive, mood and behavioural disorders. The societal cost of the disability

Table 1.1 List of ICD-10 codes which refer to traumatic brain injury

ICD code	Category
S06	**Intracranial injury**
S06.0	Concussion
S06.1	Traumatic cerebral oedema
S06.2	Diffuse brain injury
S06.3	Focal brain injury
S06.4	Epidural haemorrhage
S06.5	Traumatic subdural haemorrhage
S06.6	Traumatic subarachnoid haemorrhage
S06.7	Intracranial injury with prolonged coma
S06.8	Other intracranial injuries
S06.9	Intracranial injury, unspecified
S07	Crushing injury of head

Source: International Statistical Classification of Diseases and Related Health Problems, 10th Revision. Version for 2016 published by the WHO http://apps.who.int/classifications/icd10/browse/2016/en

Table 1.2 Sources of data on accidents and injury in the UK and on TBI

- Hospital record/statistics (including A & E departments): presentation to health services is dependent on severity of head injury and proximity/access to services.
- Mortality data: the most reliable and complete source of information on deaths due to external causes (www.statistics.gov.uk).
- HASS and LASS (Home and Leisure Accident Surveillance System): a reliable source of information on home and leisure accidents, dependent on data from A & E departments (www.hassandlass.org.uk).
- Health and Safety Executive: collects data on serious employment-related injuries and accidents (www.hse.gov.uk).
- TARN: the Trauma Audit and Research Network (www.tarn.ac.uk).
- CENTER-TBI: Collaborative European NeuroTrauma Effectiveness Research in TBI (www.center-tbi.eu).
- TRACK-TBI: Transforming Research and Clinical Knowledge in Traumatic Brain Injury (https://tracktbi.ucsf.edu).
- TBI-Prognosis Study (www.tbi-prognosis.ca/).
- InTBIR: International Initiative for Traumatic Brain Injury Research (https://intbir.nih.gov/).

following TBI can be substantial due to loss of years of productive life and a need for long-term or lifelong services. In the USA in 2009, there were 3.5 million TBI diagnoses, including 2 million A & E department visits, 300 000 hospitalisations and 53 000 deaths.[4] It has been estimated that 5.3 million people have some TBI-related disability, impairment, complaint or handicap in the USA. Similarly, it has been estimated that 6.2 million people in the European

Union (EU) have some form of TBI-related disability. The unemployment rate following TBI requiring inpatient rehabilitation has been reported as 60.4% at 2 years post-injury.[5]

Incidence of TBI

Incidence is a count of *new cases* of TBI in the population during a specified time period. The *incidence rate* is the number of *new cases* of TBI in a defined population within a specified time period (usually a calendar year), divided by the total number of persons in that population (usually expressed as per 100 000 population). Like most conditions, the incidence of TBI varies according to age, gender and geographic location. Most of the published reports are from developed countries in Europe and North America, and there is little information on epidemiology of head injury from most developing countries. The annual incidence rates of reported TBI range from a low of 47 per 100 000 population in Spain to a high of 811 per 100 000 in New Zealand (Table 1.3). Most rates are in the range of 150–450 new cases per 100 000 per year. The variation observed could be partly explained by differences in criteria used to define TBI or

Table 1.3 Incidence of traumatic head injury in different populations (selected studies)

Population	Annual incidence per 100 000 population	Male:female ratio
Africa		
South Africa, Johannesburg (Nell & Brown, 1991)	316	4.8:1
Asia		
Iran (Rahimi-Movaghar & Saadat 2011)	56	4.3:1
India (Gururaj et al. 2004)	160	NR
Taiwan, Taipei City (Chiu et al. 2007)	218	1.9:1
Europe		
Spain (Perez et al. 2012)	47[b]	2.0:1
Norway, Oslo (Andelic et al. 2008)	83[b]	1.8:1
Spain, Cantabria (Vazquez-Barquero et al. 1992)	91	2.7:1
Finland (Alaranta et al. 2000)	95	1.5:1
Finland (Koskinen & Alaranta, 2008)	101	1.5:1
Portugal (Santos et al. 2003)	137	1.8:1
Denmark (Engberg & Teasdale, 2001)	157	2.2:1
Italy, Northeast (Baldo et al. 2003)	212	1.6:1
Finland, Southeast (Numminen et al. 2011)	221[c]	1.2:1
Norway, Tromso (Ingebrigtsen et al. 1998)	229	1.7:1
UK, England (Tennant, 2005)	229	NR

Table 1.3 (cont.)

Population	Annual incidence per 100 000 population	Male:female ratio
Netherlands (Scholten et al. 2014)	242 males 175 females	1.4:1
Sweden (Kleiven et al. 2003)	259	2.1:1
UK, Staffordshire (Hawley et al. 2003)	280[a]	1.8:1
France, Aquitaine (Tiret et al. 1990)	282	2.1:1
Italy, Romagna (Servadei et al. 2002)	297	1.6:1
Austria (Mauritz et al. 2014)	303[d]	1.4:1
Italy, Trentino (Servadei et al. 2002)	332	1.8:1
Germany (Rickels et al. 2010)	332	1.4:1
Germany (Steudel et al. 2005)	337	NR
Germany (Firsching & Woischneck, 2001)	350	NR
Sweden, Northern (Styrke et al. 2007)	354	1.2:1
UK, Scotland (Shivaji et al. 2014)	446[b] males 195[b] females	2.3:1
UK, Southwest England (Yates et al. 2006)	453	1.6:1
Sweden, Western (Andersson et al. 2003)	546	1.4:1
North America		
USA, Alaska (Sallee et al. 2000)	105	2.3:1
USA, Utah (Thurman et al. 1996)	109	2.2:1
Canada, Ontario (Colantonio et al. 2010)	190[e] males 100[e] females	1.9:1
USA (Guerrero et al. 2000)	392	1.6:1
USA (Jager et al. 2000)	444	1.7:1
Oceania		
Australia, NSW (Tate et al. 1998)	100	NR
Australia, South (Hillier et al. 1997)	322	2.3:1
New Zealand, Hamilton and Waikato District (Feigin et al. 2013)	811[d]	1.8:1
USA (Taylor et al. 2017)	890[d] (2013) 625[d] (2007)	1.2:1 (2013)

Note. This table is adapted from data reviewed by Tagliaferri et al.[6] with permission. NR = not reported. [a]In children aged ≤15 years. [b]Figures for hospital admissions. [c]Figures for all cases with symptoms of brain injury after head trauma collected from health centres and hospitals; excluding mild cases of TBI reduced incidence to 137. [d]Figures for hospital discharges, outpatients and deaths in and out of hospital. [e]Figures for hospital admissions and emergency department visits.

identify patients. In a recent study from England, the incidence rates of head injury varied by a factor of 4.6 across different health authorities (range 91–419 per 100 000). Similarly, in the USA, incidence rates of TBI vary from a low of 101 per 100 000 in Colorado to a high of 367 per 100 000 in Chicago. In a review of TBI epidemiology in the EU in 2006, an overall average rate of 235 per 100 000 per year was obtained. A review of TBI in Europe in 2015 reported an incidence rate of 262 per 100 000 for admitted TBI patients.

Association of TBI with Other Structures

It is important to consider TBI in the context of the skull and other structures above the neck, as well as to identify those with 'isolated' head injuries and those with multisystem polytrauma, where other injuries may contribute to secondary brain injury. In patients with a severe brain injury (GCS 8 or less), there is a 5% incidence of associated cervical spine fractures. About 50%–60% of severe TBI patients may have one or more other organ system injuries which may contribute to secondary insult.

Variation by Age

The median age in studies of TBI ranges from 29 to 45 years worldwide. In most studies, three distinct peaks in the incidence of TBI are noted: in children, young adults and the elderly population. The highest incidence reported now is in the elderly population. It is unclear whether this is a real increase or an improvement in reporting and case ascertainment. In the USA in 2013, more than 1 in 50 adults aged 75 years or older experienced a TBI resulting in A & E attendance, admission or death. In 2013, adults aged 75 years or older accounted for 31.4% of TBI-related hospitalisations and 26.5% of all TBI-related deaths. The next highest incidence is in children aged 0–4 years with an incidence rate of 1591 per 100 000. In one UK trauma centre, 80% of elderly patients admitted had a moderate or severe TBI with 78% survival and 57% having a good outcome.[10] In young adults, road traffic accidents (RTAs) are the most frequent cause of TBI.

Variation by Gender

Almost all studies show a male preponderance. Overall, males are about twice as likely as females to experience a TBI. For studies from Europe and North America, the male:female ratio varies from 1.2:1 in Sweden to 2.7:1 in Spain. Males in developing countries apparently have a much higher risk of TBI compared with those in developed countries. In a study from South Africa, the male:female ratio was 4.8:1 (Table 1.3). In the EBIC study of severe head injuries, 74% of the patients were males.[11] In the Traumatic Coma Data Bank of patients with severe head injury, about 77% were males.[12] In the CRASH study of the effect of corticosteroids on death within 14 days, which included 10 008 patients with clinically significant head injury, 81% were males.[13] The male excess of TBI is attributed to greater exposure and more risk-taking behaviour. At younger ages the exposure of males to violence and RTAs leads to a male:female ratio of head injury incidence of about 4:1.

Severity of TBI

The reported severity of TBI depends on the population studied and case ascertainment. In a systematic review of TBI over the world in 2016, including 60 reports, the severity levels were mild (GCS 13–15; 55%), moderate (GCS 9–12; 27.7%) and severe (GCS 3–8; 17.3%).[7]

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In the pooled data from the CRASH and IMPACT studies, the severity levels were mild (20.8%), moderate (22.2%) and severe (57%).[2,3] In a study of TBI in Europe in 2015, the proportion of mild TBIs varied between 71% and 97.5%.[9]

In a study from the UK, a rate of 40 per 100 000 was found for moderate to severe (10.9%) head injuries with a Glasgow Coma Scale of ≤12. A figure of 4000 patients a year requiring neurosurgery in the UK has been reported. In the paediatric population aged 0–14 years, an incidence rate of 5.6 per 100 000 per year has been reported for admission to intensive care following a head injury.[14]

Mortality from TBI

The *mortality rate* is the number of deaths from TBI in a defined population within a specified time period (usually a calendar year) divided by the total number of persons in that population (usually expressed as per 100 000 population). The mortality rate varies considerably in different countries. In the UK, the mortality rate from head injury is 6–10 per 100 000 population per year. For France, a mortality rate of about 22 per 100 000 has been reported. In the EU, the mortality from TBI varies from a low of 9.4 per 100 000 in Germany to a high of 24.4 per 100 000 in Ravenna, Italy, with an overall average rate of 15 deaths per 100 000 population per year in 2006. In 2013 the mortality from TBI in Europe was reported as 10.5 per 100 000. In the USA, the overall mortality rate is 20–30 per 100 000, with half of the patients dying out of hospital. Amongst adults in Johannesburg, South Africa, a much higher mortality rate of 138 per 100 000 for males and 24 per 100 000 for females has been reported, with 20% of TBIs resulting in death. In the pooled data of 15 900 patients from the CRASH database and IMPACT database, the mortality was 23.8%.

Causes of Head Injury

The most common causes of TBI are falls, RTAs, assault/violence, 'struck by' or 'struck against' events and sporting or recreation activities (Figures 1.1 and 1.2). The majority of reports now show falls as the leading cause of TBI in developed countries (34.4%), whilst RTAs are the main cause in developing countries (42.4%).[7] In a review of studies from the EU in 2006, 21%–60% of TBIs were caused by RTAs (from a low of 21% in Norway and the UK to a high of 60% in Sweden and Spain) and 15%–62% were caused by falls (15% in Italy, 62% in Norway).[9] In a review of TBI in Europe in 2015, falls were the most common mechanism of injury in 14 out of 25 studies included.[9] One study from Glasgow, Scotland, reported violence/assault (28%) as the second most common cause after falls (46%). Overall, it has been estimated that in Europe, 40% of TBIs are caused by RTAs, 37% are caused by falls, 7% are caused by violence/assault and 16% result from other causes.[6]

It may be realised that the cause–effect relationships between the mechanisms of injury and TBI are confounded by age, gender, car ownership, urban residence and socioeconomic factors. Elderly people who have a relatively high incidence of falls are more likely than other age groups to be pedestrian victims of RTAs. The contributing factors may include side effects of medication, poor vision/hearing, slow reaction time and impairment of balance and mobility. In a study of TBI in children, the most common cause of injury was accidents involving children as pedestrians (36%), followed by falls (24%), cycling accidents (10%), motor vehicle occupants (9%) and assault (6%).[19] In a UK study of minor head injury in adults, the common causes of injury were assault (30%–50%), RTAs (25%) and falls (22%–43%).[10] In the USA, gunshot wound to the head is now a more frequent cause of serious head injury than RTA, with a case

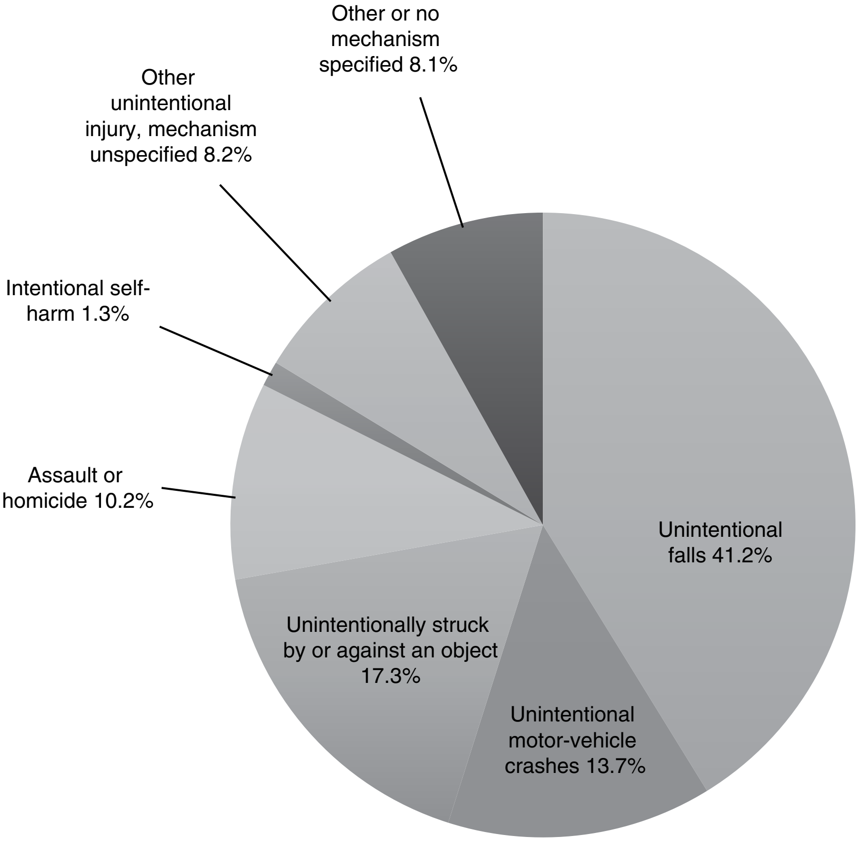

Figure 1.1 Percentage of TBI-related emergency department visits, hospitalisations and deaths by external cause in males in the USA, 2013. From Taylor et al.[8]

fatality of about 90%.[9] In a study from Canada, RTAs accounted for 43% and assault for 11% of head injuries. In the EBIC study of patients admitted to neurosurgical units (with GCS ≤ 12), 51% were involved in a RTA, 12% in a fall and 5% in an assault.[3] In the CRASH trial, RTAs accounted for 64% and falls for 13% of all head injuries.

Alcohol and TBI

It is reported that alcohol might be involved in 65% of adult head injuries. Alcohol intoxication was reported as being present in 32% of fatal motor vehicle accidents in the USA. In patients with TBI, 35%–81% are alcohol intoxicated and 42% of TBI patients were heavy drinkers before the injury. A history of alcohol abuse prior to TBI is also a strong predictor of heavy drinking after TBI.[15]

Sporting Head Injuries

The study of the epidemiology of TBI in sports is an area where significant advances in the prevention of head injuries by alteration of rules of participation and protective equipment

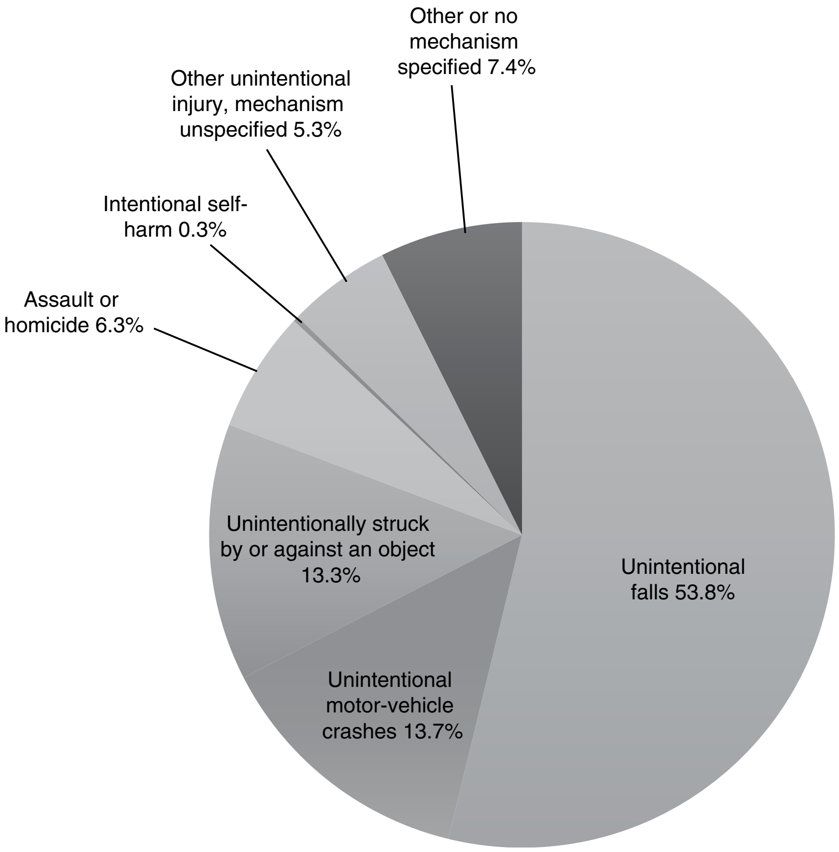

Figure 1.2 Percentage of TBI-related emergency department visits, hospitalisations and deaths by external cause in females in the USA, 2013. From Taylor et al.[8]

have been made. Media reporting of high-profile sports injuries may give the perception of a much higher incidence rate than actually occurs both within the sport and compared to other activities.

Overall, sports and recreation may account for up to 5%–10% of head injuries in studies of mechanism. Non-fatal TBIs from sports and recreational activities are reported for hospital emergency department presentations in the USA from 2001 to 2005 as part of the National Electronic Injury Surveillance System – All Injury Program. An estimated 207 830 patients with sports- and recreation-related TBIs accounted for 5.1% of sports-related emergency department visits. Approximately 10.3% of patients with sports-related TBIs required subsequent transfer to a specialist facility or hospitalisation. The most frequent causes of TBI were horse riding (11.7%), ice-skating (10.4%), riding all-terrain vehicles (8.4%), tobogganing/sledding (8.3%) and bicycling (7.7%). American football accounted for 5.7% and combative sports including boxing, wrestling, martial arts and fencing made up 4.8%.[16]

Much work has been done on the epidemiology of American football-related head injuries. The annual rate of non-fatal head-related catastrophic injuries in American football has averaged around 0.3 per 100 000 for high school and college participants. The rate of fatal injuries has stabilised at 0.32 per 100 000 per year.[17]

Prevention of Head Injury

Most TBI cases present with characteristic patterns of injury that are predictable and potentially preventable. Identification of risk factors is therefore a prerequisite for devising preventive measures and public health policy. Attempts at reducing trauma from all mechanisms will also have the effect of reducing TBI to varying degrees. The prevention programmes for TBI focus on RTA prevention, cessation of drinking and driving, minimising falls (particularly in the elderly), reducing sport injuries and decreasing violence and domestic abuse (particularly child abuse). Based on the standard principles of public health, William Haddon Jr, the first director of National Traffic Safety Bureau in the USA, proposed a conceptual model in the 1970s, the Haddon matrix, to address the problem of traffic safety.[18] The matrix illustrates the interaction of three factors – human, vehicle and environment – during three phases of an accident event – pre-accident, accident and post-accident. This concept can be successfully applied to the primary, secondary and tertiary prevention of RTAs and other types of accidents (Table 1.4). In the USA, the remarkable reduction in mortality attributed to RTAs has been hailed as one of the main public health achievements of the twentieth century.

Table 1.4 Haddon's matrix as applied to TBI in the elderly population

	Factors		
Phase	**People**	**Cause**	**Environment**
Pre-injury (accident prevention)	Co-morbidity Arrhythmia Dementia Balance Frailty Polypharmacy Visual impairment	Trip hazards Use of ladders Poor lighting	Awareness of risk of falls Handrails Non slip flooring Safe environment Footwear Balance aids
Injury (accident identification and limitation)	Associated reason for fall (e.g. MI, stroke) Anticoagulants	Lack of functional reserve Pre-injury conscious level may be impaired Injury severity may be greater in elderly	Hardness of floor Personal alarms Availability of emergency services
Post-injury (accident recovery)	Multidisciplinary care Balance classes/fall prevention Rehabilitation	Identification of causes of deterioration (e.g. haematoma expansion, chest infection, hyponatraemia, seizures)	Rehabilitation services Social support Occupational therapy Assessment of home environment before return

Legislative policy and enforcement to control motor vehicle accidents by making wearing of helmets compulsory for cyclists and motorcyclists and reducing legal permissible alcohol levels for driving have been shown to be associated with a reduction in RTA-associated head injuries.[19] Several studies have shown that the wearing of helmets by cyclists reduces the risk of head injury. In the Cochrane review of case-control studies, safety helmet use was associated with a 63%–88% reduction in the incidence of brain injury for all ages of cyclists. This protection was provided for crashes involving motor vehicles (69%) and all other causes (68%).[20] Evidence that wearing of helmets reduces injuries in skiers and snowboarders is also compelling.[21] Systematic reviews have shown that it is possible to reduce the incidence of falls by about 35% amongst older people.[22] Considering the wider determinants of public health, the role of health education and environmental engineering has been emphasised in the prevention of TBI.

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