1 Epidemiological Aspects

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1.1 Introduction

Injuries are a significant cause of disability and death. Based on the estimations of the Global Burden of Diseases study (GBD), in 2013 globally 973 million people sustained an injury requiring medical attention and about 4.8 million died from an injury (Haagsma et al. 2016). TBIs are among the most severe injuries. In the European Union (EU), estimated 2.5 million people sustain a TBI annually (Maas et al. 2017), of which about 1.5 million people are admitted to hospital, and 57,000 people die (Majdan et al. 2016).

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Epidemiological data are key for influencing the occurrence and outcome of any disease. They provide data on how often diseases occur, what their causes are, which populations are at highest risk, and the impacts on the level of individuals and populations.

Valid epidemiological data on TBI are not yet sufficient, but both the quality and quantity of available information have improved over the past decades. Three systematic reviews have summarized epidemiological data on TBI for Europe (Brazinova et al. 2018; Peeters et al. 2015; Tagliaferri et al. 2006). The most recent study (Brazinova et al. 2018) identified 84 methodologically valid studies presenting data on regional or national level.

It should be noted that systematic reviews synthesize data from epidemiological studies with substantial differences in study population, case ascertainment procedures, study period, and other aspects. This potentially causes bias and complicates pooled estimates. Some of these limitations can be overcome by using uniform case ascertainment procedures and a common study period, and by overseeing or validating the data collection. Examples of such practices are surveillance systems, such as the one implemented in the US (Taylor et al. 2017), trauma registries, or studies using uniform data for their analyses (Majdan et al. 2016, 2017).

Incidence, prevalence, mortality, and case fatality rates are all traditional epidemiological

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indicators used to describe the occurrence and outcome of diseases and injuries. They provide excellent data on the number of occurring and existing cases, but are not able to fully capture the impact of a disease in its full width, especially in case of heterogenic conditions as TBI. Therefore, modern indicators providing more detailed information about the true burden to individuals and populations are increasingly used. Among these are years of lost life (YLL), years lived with disability (YLD), disability adjusted life years (DALY), and healthy life expectancy (HALE). These indicators were introduced and used for example in the GBD study (GBD 2017 DALYs and HALE Collaborators 2018). Table 1.1 provides an overview of all these indicators and their use.

When estimating epidemiological patterns of TBI, case ascertainment is of key importance. While studies on hospital cohorts of patients with TBI have their limitations in terms of generalizability, they usually provide a good opportunity to define and characterize TBI in detail. On the other hand, studies relying on administratively collected data using ICD definitions (such as databases of causes of deaths or hospital discharges) provide a convenient way to compare epidemiological characteristics over time, or between populations of different countries. The disadvantage is that investigators do not have the possibility to validate the given diagnosis and therefore have to rely on the coding provided. This may cause biased results. A number of studies using administratively collected data use the ICD definition of head injuries to describe TBI epidemiology (Majdan et al. 2016, 2017; Brazinova et al. 2018; Mauritz et al. 2014). Although some of the minor head injuries do not include a TBI, the similarities in the incidence of TBI-related hospital discharges estimated using data from hospital cohorts (Brazinova et al. 2018; Peeters et al. 2015; Tagliaferri et al. 2006) and administrative sources (Majdan et al. 2016) suggest that ICD-10 head injury codes provide a reasonable estimate of hospital discharges due to TBI. In fact, in multiple investigations, ICD

Table 1.1 Indicators of occurrence, outcome, and burden used to describe the epidemiological patterns and impact of TBI in populations

Measure	How to calculate	What it expresses
Incidence rate	The number of new cases in a given time period divided by the total population from which they are drawn	A measure of the risk of developing some new condition within a specific period of time
Prevalence rate	The total number of persons with the observed condition (old and new cases) divided by the total population from which they are drawn	A measure of how common a condition is within a population at a certain time
Mortality rate	The number of persons dying from the condition per unit time (e.g. year) divided by the total population from which they are drawn	A measure of the number of deaths in a population, scaled to the size of the population within a specific period of time
Case fatality rate	The number of persons dying from the condition per unit time (e.g. year) divided by the total number of persons in the population with the same condition	A measure of the ratio of deaths within a designated population of people with a particular condition over a certain period of time
Years of life lost (YLL)	Reference age (life expectancy in the population) minus age of death = years of life lost	A measure of potential years of life lost. The reference age corresponds to the life expectancy of the population, commonly set at age 75
Years lived with disability (YLD)	Reference age minus age of onset of condition/disease = YLD	A measure of the years lived with the impact of disability
Disability-adjusted life year (DALY)	YLL + YLD = DALY	A measure of overall disease burden, expressed as the number of years lost due to ill health, disability or early death

Adopted from Management of Severe Traumatic Brain Injury—Evidence, Tricks and Pitfalls (Sundstrom et al. 2012) codes have been shown to underestimate the incidence of TBI (Barker-Collo et al. 2016; Deb 1999; Shore et al. 2005).

1.2 Causes

In general, road traffic accidents (RTAs) and falls are the two major external causes of injury leading to TBI (Maas et al. 2017; Majdan et al. 2016; Brazinova et al. 2018; Peeters et al. 2015; Tagliaferri et al. 2006). Previously, RTAs were the most important cause. In recent years, a decline in the number of road traffic accidents and ageing of the population has caused a transition in the relative proportions of RTAs and falls as causes for TBI in high-income countries (Roozenbeek et al. 2013). The Nordic countries have a zero-vision for traffic deaths, and this goal has been approached for several months in a row in some regions (https://www.ssb.no/en/transport-og-reiseliv/statistikker/vtu). Falls are indeed nowadays the dominant cause in many countries (Maas et al. 2017). Based on data extracted from death certificates, falls were the predominant cause of fatal TBI in Europe in 2012, followed by RTAs, suicides, and violence (Majdan et al. 2016; Brazinova et al. 2018; Peeters et al. 2015). The causes of non-fatal TBI can be estimated from hospital cohorts, registry-based studies, or surveillance data, and they display a similar pattern: falls are predominant, followed by RTAs (Brazinova et al. 2018; Peeters et al. 2015; Tagliaferri et al. 2006).

1.3 Incidence

The reported incidence of TBI varies widely in published studies. In Europe, it ranges from 47 to 694 new cases per 100,000 people per year (Brazinova et al. 2018). Much of this variation is probably caused by differences in study designs or case ascertainment. Two summary estimates of TBI incidence for Europe were recently published (Majdan et al. 2016; Brazinova et al. 2018), and they are close to each other; 262 and 287.2 per 100,000 people per year, respectively. The former estimate is based on a meta-analysis of incidences from published studies (including hospital cohorts and studies using administrative data and the broader definition of head injuries) (Peeters et al. 2015) and the latter on hospital records from a single year from 25 European countries (using the broader definition of head injuries based on ICD-10) (Majdan et al. 2016). An estimate of the relative proportion of the head vs. brain injuries suggested that about 56% of all head injuries treated as inpatient were also intracranial injuries (Majdan et al. 2016). Capturing TBI in the whole range of its severity can lead to incidences, which are substantially higher; for example, a community-based study in New Zealand about TBIs of all severities resulted in 790 cases of TBI per 100,000 person years (Feigin et al. 2013).

1.4 Mortality and Case Fatality

Deaths as a consequence of TBI are usually reported using two different indicators: case fatality rates indicate the proportion of fatal cases of all TBI cases per unit of space and time, and mortality indicates the number of cases relative to the overall population.

Most studies of hospital cohorts report case fatalities, and these vary widely based on the characteristics of the cohort: in a systematic review, they ranged from 1 to 60%, with recent studies on TBI of all severities reporting 16–25% and those based on cohorts of severe TBI reporting about 50% (Brazinova et al. 2018). With increasing age, case fatality rates increase: a meta-analysis of TBI cases in those over 60 years of age showed a rate of 57% (McIntyre et al. 2013).

The close correlation with age is apparent in mortality rates as well. Based on data from death certificates, the proportion of persons 65 years or older among deaths due to TBI was 55%, and in females as high as 68% (Majdan et al. 2016). Mortality also varies from study to study and between countries, although not to a degree observed in case of incidences: in a systematic review, mortality ranged from 6 to 12 per 100,000 population (Brazinova et al. 2018), and in an analysis of death certificate data from 25 European countries, between 2.8 and 20.3 per 100,000 (Majdan et al. 2016). The pooled mortality rate in Europe has been estimated to 11.7 cases per 100,000 people, and TBIs caused 37% of injury deaths in Europe (Majdan et al. 2016). An important aspect of mortality after a TBI is the time after injury at which the death occurs. Usually, deaths in the ICU, before hospital discharge and by 6 months post injury are reported in the literature. The time of survival after the injury in general has implications for the burden and cost of TBI to society. This is dealt with in other parts of this book in greater detail.

1.5 The Burden of TBI and Global Aspects

The epidemiology of TBI is increasingly being studied using modern indicators of the burden of disease. A recent study from New Zealand estimated that 20,300 DALYs can be attributed to TBI in New Zealand (Te Ao et al. 2015), while a study from the Netherlands estimated 171,200 TBI-related DALYs (Scholten et al. 2014). A study based on detailed data on causes of death from 16 European countries estimated that about 17,000 TBI-related deaths resulted in about 375,000 YLLs, which translates to about 259 TBI-related YLLs per 100,000 people, or to about 24.3 years of lost life per TBI death (Majdan et al. 2017). For the year 2016, the burden of TBI is estimated on a global scale within the GBD study, but due to limitations of causes of death data, it is restricted to YLDs, resulting in 8.1 million YLDs (GBD 2016 Traumatic Brain Injury and Spinal Cord Injury Collaborators 2019).

Greatly contributing to the global occurrence of TBI are developing countries with growing economies, where road traffic is increasing rapidly while authorities are not able to keep up with preventive and control measures. It is estimated that one TBI death occurs in India every 3 min, and annually about one million people become disabled due to TBI, of which 60–70% are caused by RTAs (Maas et al. 2017). Similarly in China, RTAs are the main cause of TBI, accounting for about 54% of cases (Maas et al. 2017). The age-adjusted TBI mortality rate increased from 13 in 2003 to 17 per 100,000 population in 2008 (Cheng et al. 2017). In the USA, each year about 2.5 million are admitted to EDs, hospitalized, or die due to TBI, as estimated in 2010 by the CDC (Taylor et al. 2017). There is a massive lack of information from low- and middle-income countries where the incidence, mortality, and general burden is presumably much higher than in Europe and the USA.

Disease prevalence is the most appropriate indicator for assessing the need for care and continuous health services. In case of TBI, the information on prevalence (e.g. the number of people alive with a sequelae after TBI at a point in time) is very limited. Those few estimates that are available are mostly based on self-report surveys and may thus be biased. A systematic review summarized the available findings and reported lifetime history of TBI in about 12% of the interviewed persons, 17% in males and 9% in females (Frost et al. 2013). A more precise estimation was derived from a Swedish birth cohort where 9.1% of the cohort members sustained a TBI before the age of 25 years, but the percentage of those with permanent symptoms was not studied (Sariaslan et al. 2016). Another approach of estimating the prevalence is mathematical modelling. With this approach, the prevalence in the general population of New Zealand was calculated at 13% (11.4% in females and 14.8% in males) (Te Ao et al. 2015). On the global scale, the prevalence has been modelled in the GBD study, where the global prevalence of TBI was estimated at 55.5 million cases (GBD 2016 Traumatic Brain Injury and Spinal Cord Injury Collaborators 2019).

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