Estimating the global incidence of traumatic brain injury

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OBJECTIVE Traumatic brain injury (TBI)—the “silent epidemic”—contributes to worldwide death and disability more than any other traumatic insult. Yet, TBI incidence and distribution across regions and socioeconomic divides remain unknown. In an effort to promote advocacy, understanding, and targeted intervention, the authors sought to quantify the case burden of TBI across World Health Organization (WHO) regions and World Bank (WB) income groups.

METHODS Open-source epidemiological data on road traffic injuries (RTIs) were used to model the incidence of TBI using literature-derived ratios. First, a systematic review on the proportion of RTIs resulting in TBI was conducted, and a meta-analysis of study-derived proportions was performed. Next, a separate systematic review identified primary source studies describing mechanisms of injury contributing to TBI, and an additional meta-analysis yielded a proportion of TBI that is secondary to the mechanism of RTI. Then, the incidence of RTI as published by the Global Burden of Disease Study 2015 was applied to these two ratios to generate the incidence and estimated case volume of TBI for each WHO region and WB income group.

RESULTS Relevant articles and registries were identified via systematic review; study quality was higher in the high-income countries (HICs) than in the low- and middle-income countries (LMICs). Sixty-nine million (95% CI 64–74 million) individuals worldwide are estimated to sustain a TBI each year. The proportion of TBIs resulting from road traffic collisions was greatest in Africa and Southeast Asia (both 56%) and lowest in North America (25%). The incidence of RTI was similar in Southeast Asia (1.5% of the population per year) and Europe (1.2%). The overall incidence of TBI per 100,000 people was greatest in North America (1299 cases, 95% CI 650–1947) and Europe (1012 cases, 95% CI 911–1113) and least in Africa (801 cases, 95% CI 732–871) and the Eastern Mediterranean (897 cases, 95% CI 771–1023). The LMICs experience nearly 3 times more cases of TBI proportionally than HICs.

CONCLUSIONS Sixty-nine million (95% CI 64–74 million) individuals are estimated to suffer TBI from all causes each year, with the Southeast Asian and Western Pacific regions experiencing the greatest overall burden of disease. Head injury following road traffic collision is more common in LMICs, and the proportion of TBIs secondary to road traffic coll...
TRAUMATIC brain injury (TBI), often referred to as the "silent epidemic," remains a growing public health concern and represents the greatest contributor to death and disability globally among all trauma-related injuries. Previous studies from the United States and New Zealand have estimated approximately 500–800 new cases of TBI per 100,000 people each year. However, estimates of the TBI burden from low- and middle-income countries (LMICs) are scarce. A large survey-based study in 8 LMICs identified a lifetime prevalence of TBI from < 1% (China) to nearly 15% (Mexico and Venezuela) of the studied population, with most estimates approximating those from high-income countries (HICs). Efforts to identify reliable epidemiological data on the incidence of and the disability and mortality from TBI in resource-poor settings are still needed.

Road traffic collisions are a significant source of TBI. Using national registries, population-based literature, and statistical modeling, the Global Burden of Disease (GBD) Study 2015 (GBD 2015) estimated the incidence of road traffic injuries (RTIs) in countries worldwide. By understanding the relationship between RTI and TBI, the incidence of TBI can be estimated. Because the interaction between RTI and TBI probably differs across regions of various populations, regulations, and infrastructures, a region-specific estimate of this relationship is essential to ensure accurate TBI estimates.

Beyond a fundamental disparity in quality data, a majority of the global population resides in LMICs, underscoring the need for reliable estimates of the TBI burden in resource-poor settings. In this comprehensive review, we provide estimates for TBI across geographic regions and income groups to deliver a global estimate of the volume and burden of TBI worldwide.

Methods

Overview

Incidence figures and overall disease volume were calculated from literature reviews, national registries, the GBD initiative, and the World Bank (WB). A similar methodology of estimating the frequency of traumatic injuries in LMICs has been described elsewhere. A flowchart illustrates the contribution of relevant data sources and a stepwise progression in our methodology (Fig. 1). Initially, the incidences of RTI in different countries were obtained from the Institute for Health Metrics and Evaluation (IHME) GBD dataset. The incidences of RTIs were converted to population-based rates, that is, P(RTI), which represents the proportion of RTIs in a given population (that is, the probability that a person living in a country will sustain an RTI in a year; Fig. 1 II). By multiplying P(RTI) by the country population, we were able to obtain the RTI\(_{\text{TOTAL}}\), representing the total number of RTIs in a country annually (Fig. 1 III):

\[
\text{RTI}_{\text{TOTAL}} = P(\text{RTI}) \times \text{Population}.
\]

We next sought to obtain the number of patients who had sustained a TBI or head injury (HI) from total RTIs, represented by RTI\(\cap\)TBI (that is, the intersection of RTI\(_{\text{TOTAL}}\) and TBI\(_{\text{TOTAL}}\); Fig. 1). To this end, we conducted a systematic review and meta-analysis of studies reporting the proportion of RTIs that had resulted in TBIs in different WHO regions and income groups. This proportion is expressed as a probability value, P(TBI|RTI), that is, the proportion sustaining TBI after RTI (Fig. 1 IV):

\[
P(\text{TBI}|\text{RTI}) = \frac{\text{RTI} \cap \text{TBI}}{\text{RTI}_{\text{TOTAL}}}.
\]

By multiplying the RTI\(_{\text{TOTAL}}\) by P(TBI|RTI), we obtained the total number of patients who sustained TBI after RTI (Fig. 1 V):

\[
\text{RTI} \cap \text{TBI} = \text{RTI}_{\text{TOTAL}} \times P(\text{TBI}|\text{RTI})
\]

Understanding that traffic collisions are one of many TBI mechanisms of injury (MOIs), we sought the proportion of TBIs that are caused by RTIs. Accordingly, we conducted another systematic review and meta-analysis, this time to quantify the proportion of TBIs with RTI as the MOI in different WHO regions and income groups. This proportion is expressed as a probability value, P(RTI|TBI), that is, the proportion of TBIs secondary to RTIs (Fig. 1 VI):

\[
P(\text{RTI}|\text{TBI}) = \frac{\text{RTI} \cap \text{TBI}}{\text{TBI}_{\text{TOTAL}}}.
\]

Multiplying RTI\(\cap\)TBI by the inverse of P(RTI|TBI) and thereby accounting for the non-RTI causes of TBI, we obtained the total number of TBI cases annually in different WHO regions and income groups (Fig. 1 VIII):

\[
\text{TBI}_{\text{TOTAL}} = \frac{\text{RTI} \cap \text{TBI}}{P(\text{RTI}|\text{TBI})}
\]

\[
\text{TBI}_{\text{TOTAL}} = \frac{\text{RTI} \cap \text{TBI}}{P(\text{RTI}|\text{TBI})}
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\[
\text{TBI}_{\text{TOTAL}} = \frac{\text{RTI} \cap \text{TBI}}{P(\text{RTI}|\text{TBI})}
\]

A more detailed explanation of our methodology is outlined below.

Incidence of RTIs

To identify the proportion of the population that sus-
tains an RTI every year, we obtained and extracted relevant data on the incidence of RTI from the IHME GBD dataset by using the open-access site vizhub.healthdata.org/epi. 116 Region-specific data sources included the World Health Organization (WHO) regional office, ministries of health, and so forth, while mixed-effects-modeled IHME GBD data were excluded. Regions not recognized by the WB or the WHO were excluded (for example, Tibet). In a few instances, the incidence for only one sex was provided; therefore, to maintain uniformity and generalizability, incidence data that included male and female sex were selected for analysis over incidence data for just one sex.
sex. Incremental age and sex values were averaged, and mean incidence values were estimated for each country. Each incidence value was expressed as the probability that a person living in a country would sustain an RTI annually \( [P(RTI); \text{Fig. 1 II and III}] \).

The total number of RTIs \( (RTI_{\text{TOTAL}}) \) per WHO region and WB income group was calculated as the product of the WB 2015 population metadata \( ^{260} \) and the GBD RTI data. The WB metadata are modeled figures to project population changes over time.

Proportion of RTIs Causing TBIs

The probability of sustaining a TBI after an RTI is represented by \( P(TBI|RTI) \). This is equal to the ratio of RTIs with TBI to all RTI cases with or without TBI in a population \( \text{(Fig. 1 IV)} \). To identify this proportion, a systematic literature search of PubMed was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for studies reporting the proportion of RTIs resulting in TBI or HI \( \text{(Fig. 2)} \).\(^{173} \) The aim of the search was to comprehensively identify population- and hospital-based studies quantifying the injuries resulting from traffic accidents. Thus, a series of searches were performed to capture a wide range of relevant studies to calculate the proportion of TBIs or HIs resulting from the primary event of an RTI. A full description of search parameters, as well as inclusion and exclusion criteria, can be found in the Appendix. Briefly, search terms included “traffic accident,” “vehicular crash,” “vehic* accident,” “brain injury,” and “head injury.” Our search focused on “accident” as opposed to “crash” or “collision” because most epidemiological studies on road injuries have historically followed this notation convention until recently, when studies began to shift to more objective terminology. Thus, our use of “vehicular crash” was an attempt to capture more recent studies using this new convention. Articles were included if epidemiological data categorized the types of injuries sustained from RTIs and if the proportion of RTIs resulting in HI or brain injury was discernible. Studies that included only TBI or HI and those that only reported a certain severity of injury (for example, severe TBI only) were excluded to minimize selection bias. Two reviewers (A.R., S.G.) and a single arbiter (M.C.D.) conducted this search.

Next, we conducted a search of governmental traffic injury registries that reported HIs. The Organisation for Economic Co-operation and Development (OECD) Health Statistics report (“Injuries in Road Traffic Accidents 2016”) and citation information from the IHME GBD data on road injury incidence were queried.\(^{116} \) Registries from 15 different countries were screened: United States, United Kingdom, Canada, Mexico, Brazil, Australia, New Zealand, Taiwan, China, India, South Africa, Belgium, Chile, France, Italy. A single registry (United Kingdom) yielded compatible information on HI and was incorporated into the model with the peer-reviewed study data.

Study results were then pooled using MedCalc software version 15.1 to conduct a meta-analysis. Data were pooled with inverse probability random-effects weighting to estimate the proportion of RTIs resulting in TBI, represented by \( P(\text{TBI}\mid\text{RTI}) \) for each WB income group and WHO region.

The number of cases of RTI that resulted in TBI, represented by \( RTI\cap TBI \), was calculated as the product of \( RTI_{\text{TOTAL}} \) and \( P(\text{TBI}\mid\text{RTI}) \) for all WHO regions and WB income groups (Fig. 1 V).

Traumatic Brain Injury MOI

Another systematic literature review and meta-analysis
was conducted to estimate the relative distribution and proportions of MOI for TBI. The goal was to calculate the proportion of TBI cases that were attributable to RTI, represented by $P(RTI|TBI)$, or the probability that TBI resulted from RTI as a mechanism. This is equal to the ratio of TBI caused by RTI to TBI from all causes in a population (Fig. 1 VI).

Following the PRISMA guidelines, we searched the PubMed and Cochrane Database of Systematic Reviews to identify studies reporting country-specific epidemiological data on TBI MOI. A full list of search terms and the search methodology can be found in the Appendix, and a detailed breakdown of the article screening process is illustrated in Fig. 3. In summary, MeSH and title/abstract terms were included to maximize the inclusion of studies related to TBI epidemiology (incidence, prevalence, burden, mortality, and so forth) published in countries recognized by the WB. Given the scope of this review, 4 reviewers (A.R., M.P., R.E.B., Y.C.H.) and 1 arbiter (M.C.D.) screened the articles, while 5 investigators extracted relevant data from source articles (A.R., R.E.B., M.P., Y.C.H., M.C.D.). The methodological quality of individual studies was scored on a 6-point scale from lowest (0 = small sample size, hospital based) to highest (5 = large, ideal population based) to allow quality comparisons among regions and income groups. As described by Feigin et al., less rigorous study quality was permitted for studies from LMICs, from which data would otherwise be unavailable.

Mechanism of injury studies were first selected based on completeness of data (that is, the sum of individual MOI cases equaled the total number of TBI cases reported). Studies were then reviewed for study design and subject selection; studies reporting incidence within a population that could be extended beyond a hospital (that is, at least the regional level) were included for data analysis. Mechanism of injury studies were excluded if they had narrow selection criteria (only pediatric patients, only severe TBI, and so forth).

Incidence of TBIs

The total number of TBI cases from all MOIs ($TBI_{TOTAL}$) in a population annually was computed by dividing the number of TBI cases secondary to RTI ($RTI \cap TBI$) by the proportion of TBIs caused by RTIs ($P(RTI|TBI)$; Fig. 1 VII). The WB population data and $TBI_{TOTAL}$ were then used to calculate the incidence of TBI in a given population ($P(TBI)$; Fig. 1 VIII). The calculations for confidence intervals are outlined in the Supplement.

Severity of Injury

Finally, we sought to characterize the distribution of mild, moderate, and severe TBI. Studies identified in the systematic review for MOI (Methods, Traumatic Brain Injury MOI) were queried for the reporting of TBI severity. Population-based studies categorizing TBI severity with Glasgow Coma Scale scores of mild (13–15), moderate...
TABLE 1. Proportion, incidence, and volume of TBI worldwide by WB income group and WHO region

| Group       | Population | RTI∩TBI | P(RTI) | RTITOTAL | P(TBI|RTI) | TBI Incidence (cases per 100,000 people) | 95% CI     | TBI TOTAL | 95% CI     |
|-------------|------------|---------|--------|----------|---------|-----------------------------------------|------------|-----------|------------|
| LMIC        | 6,160,384,080| 0.01308 | 80,577,165 | 0.344     | 27,727,408 | 0.555                     | 49,954,794 | 30,597,109–69,312,478 | 811     | 497–1125   |
| AFR         | 990,267,592 | 0.01292 | 12,798,416 | 0.344     | 4,404,063   | 0.555                     | 7,934,534  | 7,247,018–8,622,050  | 801     | 732–871    |
| AMR-L       | 634,315,984 | 0.01368 | 8,677,844  | 0.335     | 2,906,427   | 0.504                     | 5,765,538  | 4,840,302–6,690,774  | 909     | 763–1055   |
| AMR-US/Can  | 357,270,594 | 0.01121 | 4,004,087  | 0.289     | 1,157,181   | 0.249                     | 4,640,418  | 2,323,192–6,957,645  | 1299    | 650–1947   |
| EMR         | 648,060,427 | 0.01300 | 8,425,138  | 0.330     | 2,783,097   | 0.479                     | 5,814,715  | 4,999,254–6,630,175  | 897     | 771–1023   |
| SEAR        | 1,928,530,522| 0.01529 | 29,484,574 | 0.344     | 10,145,937 | 0.555                     | 18,279,321 | 15,387,571–21,170,070| 948     | 798–1098   |
| WPR         | 1,873,450,273| 0.01405 | 26,331,186 | 0.336     | 8,853,523   | 0.511                     | 17,312,953 | 14,746,696–19,879,210| 924     | 787–1068   |

AFR = African Region; AMR-L = Region of the Americas–Latin America; AMR-US/Can = Region of the Americas–United States and Canada; EMR = Eastern Mediterranean Region; EUR = European Region; HIC = high-income country; LMICs = low- and middle-income countries; P(RTI) = probability that a member of the population will sustain an RTI annually; P(RTI|TBI) = probability that TBI is secondary to RTI; P(TBI|RTI) = probability that RTI will lead to TBI; RTI = road traffic injury; RTI∩TBI = intersection of RTIs and TBIs, thus representing either the number of RTIs that lead to TBI or the number of TBIs with RTI as the mechanism of injury; SEAR = Southeast Asia Region; TBI = traumatic brain injury; TBI TOTAL = total cases of TBI, whether mechanism is RTI or non-RTI; WPR = Western Pacific Region.

Results

Incidence of RTIs

A total of 66 countries were represented in the GBD RTI mean incidence rate data, including all 7 WHO regions—African Region (AFR) = 20 countries, Region of the Americas–Latin America (AMR-L) = 6 countries, Region of the Americas–United States and Canada (AMR-US/Can) = 1 country, Eastern Mediterranean Region (EMR) = 8 countries, European Region (EUR) = 18 countries, Southeast Asian Region (SEAR) = 6 countries, Western Pacific Region (WPR) = 7 countries—and all WB income groups (high = 16, middle = 40, low = 10). The annual incidence is displayed as a proportion of the population [P(RTI)] and was highest in the SEAR (1.5%) and lowest in the AMR-US/Can (1%); Table 1). Despite differences in the proportion of motor vehicle users across WHO regions, there was relatively minimal variability in the risk of RTI.

Proportion of RTIs Resulting in TBI

A total of 12 large RTI studies reporting data on the proportion of HIs or TBIs were identified. Five WHO regions were represented: AFR = 5 studies (4 countries), AMR-L = 0 studies, AMR-US/Can = 1 study, EMR = 0 studies, EUR = 2 studies (2 countries), SEAR = 2 studies (1 country), WPR = 2 studies (2 countries). All income groups were also represented (studies: HIC = 3, middle-income country [MIC] = 6, low-income country [LIC] = 3). Methodology, sample size, and cohort characteristics for each study can be found in Supplemental Table S1. The pooled proportion of RTIs and TBIs for each region and income group is listed in Table 1. The greatest P(TBI|RTI) was found in the AFR and SEAR (34%), whereas AMR-US/Can (29%) had the lowest proportion. This equated to 4,404,063 TBI cases related to RTI in AFR and 1,157,181 in AMR-US/Can. Despite having an equivalent or lower P(TBI|RTI) than in the AFR, the SEAR and WPR carry the greatest absolute caseload of TBIs secondary to RTIs, at 10.1 and 8.9 million new cases each year, respectively.

Traumatic Brain Injury MOI and Injury Severity

The systematic review to describe TBI epidemiology and to quantify TBI MOI yielded more than 240 full-text articles from an initial 8756 titles. Severity distribution values were pooled using random-effects inverse weighting meta-analysis in accordance with the methodology and reasoning outlined above (Methods, Proportion of RTIs Resulting in TBI). From these data, the proportion of different TBI severities was calculated and multiplied by the total TBI incidence to arrive at an estimated incidence of mild, moderate, and severe TBI across geographic regions and income brackets.
statistics, patient demographics, and study setting and design were captured in a comprehensive database of the most relevant TBI studies worldwide over the last decade. After further filtering by study population, injury setting, completeness of data, and broad/representative subject selection, we identified 10 studies reporting on 11 unique cohorts (1 study counted twice) that provided representative TBI mechanism distributions (Supplemental Table S3).18,33, 52,112,114,129,144,185,187,252 Five WHO regions (unique cohorts: AFR = 3, AMR-US/Can = 1, EMR = 2, EUR = 2, WPR = 3) and 2 WB income groups (HIC = 4, MIC = 7) were represented. The pooled proportion [P(RTI|TBI)] for each income group and WHO region is listed in Table 1. The P(RTI|TBI) was lowest in the AMR-US/Can (25%) and highest in the SEAR and AFR (56% each).

A total of 6 studies, comprising 7 distinct cohorts, were incorporated into the severity of injury estimate (4 WHO regions).33,52,125,218,228,240 Mild TBI accounted for 81.02% of injuries, moderate TBI for 11.04%, and severe TBI for 7.95% (Table 2).

Worldwide Incidence and Volume of TBI

The incidence of TBI was highest in the AMR-US/Can (1299 cases per 100,000 people, 95% CI 650–1947) and EUR (1012 cases per 100,000 people, 95% CI 911–1113) and lowest in the AFR (801 cases per 100,000 people, 95% CI 732–871; Table 1). Extrapolating onto regional populations, the greatest volume of TBI annually was observed in the SEAR (18.3 million) and WPR (17.3 million; Fig. 4). The global incidence of all-cause, all-severity TBI is estimated at 939 cases per 100,000 people worldwide each year. While the incidence of TBI was highest in the AMR-US/Can and EUR, the greatest overall burden of TBI is seen in the SEAR and WPR.

Estimates provided here are generally higher than those in previous efforts to quantify the volume of TBI. In 2010, it was estimated that 1.7 million people in the United States sustain a TBI each year,66 far fewer than our estimate of 4.6 million in the United States and Canada. However, the former report primarily examined individuals presenting to an emergency department for care and thus probably underestimated the overall population burden of TBI. Indeed, many patients who sustain a mild TBI (sports concussions, falls, low-velocity RTI) probably never seek medical attention. Zhang et al. estimated that up to 1650 adolescents per 100,000 patients suffer a concussion each year—a figure that does not include the many other types and severities of HI.266 Preliminary results from the 2010 GBD Project10 suggested that the global incidence rate of TBI was 200 cases per 100,000 people per year, equating to approximately 15 million persons affected. For comparison, an estimated 3.8 million new cases of human immunodeficiency virus, 287 million cases of malaria, and 8.8 million cases of tuberculosis will develop each year.116 In terms of other common conditions causing neurological morbidity and mortality, recent estimates suggest that each year there are 16.9 million new cases of stroke and 30 million new cases of central nervous system infection.152 Contextualizing their figure of 15 million new cases, the GBD Project authors acknowledged the uncertainty of their estimate and that it was “a likely underestimate” because they had used hospital- and emergency department–based studies. The updated GBD study (GBD 2015) used here provides more accurate figures for RTI, and our ratio estimates are based on more recent TBI studies. Furthermore, the higher prevalence of mild TBI in our estimate probably explains some of these disparities.

In calculating the incidence figures herein, we relied on RTI data from the IHME since reliable, population-based incidence figures for TBI in the majority of LMICs were unavailable—both in the literature and via national registries. Relative ratios of TBI occurrence, as well as the contribution of RTI to overall TBI, obtained via systematic review and meta-analysis are subject to multiple sources of bias. Any small difference or inaccuracy in the TBI/RTI...

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### Table 2. Characteristics and overview of TBI severity studies

| Authors & Year | Country | WHO Region | Income Level | Sample Size (no.) | Severity Index | Mild | Moderate | Severe |
|---------------|---------|------------|--------------|-------------------|----------------|------|----------|--------|
| Selassie et al., 2014 | US | AMR-US/Can | High | 33,695 | AIS | 45.7 | 19.63 | 34.67 |
| Bener et al., 2011 | Qatar | EMR | High | 1,952 | GCS | 82.94 | 9.528 | 7.53 |
| Siman-Tov et al., 2016 | Israel | EUR | High | 2,419 | GCS | 72.59 | 9.384 | 18.02 |
| Szarpak & Madzienza, 2011 | Poland | EUR | High | 1,031 | GCS | 82.44 | 10.18 | 7.37 |
| Ji et al., 2015 | China | WPR | Middle | 195,189 | Other | 78.87 | 18.51 | 2.62 |
| Chiu et al., 2007 | Taiwan | WPR | Middle | 1,474 | GCS | 82.7 | 8.82 | 8.48 |
| Chiu et al., 2007 | Taiwan | WPR | Middle | 5,754 | GCS | 87.46 | 5.89 | 6.64 |
| Overall estimate | | | | 241,514 | | 81.02 | 11.04 | 7.95 |

AIS = Abbreviated Injury Scale; GCS = Glasgow Coma Scale.

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This content is from an academic journal, and it focuses on the incidence and volume of traumatic brain injuries (TBI) worldwide, emphasizing the use of data from the Global Burden of Disease (GBD) study. The table provides a summary of studies contributing to the incidence estimates, highlighting regions with the highest and lowest TBI incidence rates, and a discussion on the limitations of previous studies compared to the current one. The authors also address the challenges in estimating TBI incidence and the potential for underestimations, particularly for mild TBI cases. The emphasis is on the need for more accurate and comprehensive data for better understanding and management of TBI.
ratio is compounded when applied to P(RTI) and regional populations. For example, in this model, a low P(RTI|TBI) will boost regional TBI incidence because incidence is calculated from the product of P(RTI) and the inverse of P(RTI|TBI). The incidence of TBI in the AMR-US/Can probably stands as an outlier in part for this very reason. While also relatively high, the EUR incidence (1012 cases per 100,000 people) is somewhat diluted by MICs, in which less robust, hospital-derived data tend to produce lower overall TBI incidence rates because some cases of mild TBI are never reported. The lower TBI incidence in the AFR is probably explained in part by lower-quality road traffic data from member countries, as well as by the overwhelming contribution of RTIs to TBI. In this model, the contribution of all other MOIs (recreation, falls, assault, and so forth) is incorporated indirectly by the inverse proportion of TBIs from RTIs (Fig. 1).

Nevertheless, several observations lending credence to our estimates warrant elaboration. First, our meta-regression suggests that P(TBI|RTI) is highest in the AFR (34%) and SEAR (34%) and lowest in the AMR-US/Can (29%). This is an intuitive finding given the abundance of traffic regulations and safety laws in places like the United States relative to many LICs. Additionally, RTI refers to injuries sustained not only by motorists, but also by pedestrians and cyclists. A dearth of sidewalks and traffic lights and poor helmet compliance among cyclists and motorists in LMICs probably translate to a higher rate of HI following RTI. Moreover, inadequate on-board safety technology or overcapacity vehicles can compound an otherwise trivial collision. The single collision of a cargo truck full of unrestrained occupants in LMICs can result in dozens of cases of TBI—a scenario not frequently observed in most HICs.

Second, we found that P(RTI|TBI) was lowest in the AMR-US/Can (25%) and highest in the SEAR (56%) and AFR (56%). A larger proportion of studies from the SEAR and AFR represented hospital-based analyses relative to studies from regions with a predominance of HICs. In many HICs, in which life expectancy exceeds that in LMICs, injury secondary to falls, especially in the elderly, tends to dilute the overall mechanistic proportion of TBI; our results suggest that this phenomenon may exist. Mild TBI occurs with far greater frequency than moderate or severe TBI—nearly 10-fold the burden of both moderate and severe injury. When establishing health care priorities in the setting of limited resources, some may dismiss this mild TBI burden as being of nominal consequence. However, the disabling effects of even mild TBI probably translate into economic, societal, and qual-

FIG. 4. Map showing incidence of TBI (cases per 100,000 people) by WHO region (left). Bar graph (upper right) indicating the estimated volume of TBI annually across WHO regions. Map (lower right) showing incidence of TBI (cases per 100,000 people) secondary to traffic collisions by WHO region. Regarding maps, reproduced with permission from OpenStreetMap Contributors, CC BY-SA 2.0 (http://www.openstreetmap.org/copyright). Figure is available in color online only.
ity of life detriments. Nearly a quarter of patients describe disabiling symptoms several months after injury.\textsuperscript{195,268} And despite the normalization of neuropsychological and functional scales by 1 year, half of TBI victims report 3 or more persistent posttraumatic symptoms.\textsuperscript{68}

The volume and extent of our literature review attempts not only to address our stated hypotheses, but also to aid researchers interested in exploring these hypotheses further. The tremendous amount of data found within these studies cannot possibly be summarized in a single paper; instead, highlights and major patterns are described in the text and tables. Readers are encouraged to consult the Supplemental Tables to gain a more granular understanding of the nature of TBI in regions around the world. Supplemental Table S2 is organized by WHO region and country to serve as a quick reference for the interested reader and those seeking an understanding of the data available in—and absent from—the literature.

Limitations and Future Directions

The conclusions of this report must be examined in the context of our study design. First, all TBI estimates were modeled after the GBD estimates for RTI. Therefore, assumptions or errors made in the GBD methodology would be carried over into these estimates. Second, by nature of the data available from the literature, we assumed uniform disease susceptibility across age groups and sexes. We also assumed that member countries of a particular WHO region or WB income group share the same injury incidence and proportion. The gold-standard alternative to this limitation is a series of large, population-based sampling studies conducted in every representative population worldwide; the feasibility and cost of such an effort is problematic, though no less important.

Next, the literature reviews and meta-analyses conducted to obtain RTI and TBI relative ratios rely on heterogeneous and often biased study designs. Naturally, a topic as broad as TBI yields results from non-uniform populations, thereby making aggregations and direct comparisons challenging. For example, in the latter systematic review, some studies only examined severe TBI\textsuperscript{14,24,25} and some only reported on TBI in young\textsuperscript{188,194,197,241,243,254,258,265} or elderly\textsuperscript{49,134,225} cohorts. Combining epidemiological data across disparate cohorts risks misrepresentation of the disease burden and volume. Moreover, the methodological quality from LMICs was, on average, lower than that from HICs; the TBI estimates from HICs may be more reliable than those from LMICs. This limitation is inherent to most global epidemiological surveys, wherein data derive from sources of disparate quality. Lastly, even basic discrepancies, such as differing definitions of TBI or conflicting injury severity scores, encountered across studies may have influenced our results.

Despite the limitations of this model and its underlying methodology, justification for its use resides in the scientific estimation of TBI burden in countries and regions in which data are otherwise entirely unavailable. Our aim of estimating the volume of TBI on a global scale in a transparent and quantitative fashion has been realized, albeit with the aforementioned considerations. Concrete estimates of TBI with region and income-level specificity are provided.

A tremendous burden—approximately 69 million cases—of TBI can be expected each year. The vast majority of this burden affects populations in LMICs, in which adequate health care resources are often either inaccessible or nonexistent. Examining the disease burden between regions and comparing against available resources allows identification of such deficits in existing health care coverage. More robust research, especially in LMICs where high-quality data are deficient, is essential for a targeted campaign. A logical first step in this effort is the establishment of an international TBI registry to improve our understanding of the nature and scope of TBI worldwide. Such a registry should be intuitive, secure, electronic, transferable across heterogeneous institutional informational technologies, and free. While there are multiple such platforms available, we have extensive experience with REDCap\textsuperscript{105} (Research Electronic Data Capture, Vanderbilt University) and its successful application in international data collection for clinical neurosurgery in LMICs. Secondarily—and concurrently—a series of targeted, community-based epidemiological surveys of representative populations would allow for the generation of more reliable incidence and mortality figures for TBI in low-resource settings. Ultimately, curbing the silent epidemic of TBI will require a multipronged effort toward public awareness, safety legislation and enforcement, injury prevention campaigns, health care capacity strengthening, and community-based efforts to promote recovery and rehabilitation.

Conclusions

Each year an estimated 69 million individuals will suffer a TBI, the vast majority of which will be mild (81%) and moderate (11%) in severity. Per capita, the highest annual incidence of all-cause TBI is observed in the AMR-US/Can and EUR (1299 and 1012 cases per 100,000 people, respectively). Taking into account regional populations, however, the greatest burden of HIs is in the SEAR (18.3 million) and WPR (17.3 million). The health care systems in LMICs encounter nearly 3 times as many total TBIs than those in HICs. These estimates are limited by relatively low-quality data from LMICs and suggest the need for more robust and accurate injury reporting. The global disparity in health care between regions with fewer resources and a high disease burden and those with greater assets and a lower burden deserves attention and action.

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Appendix

Search Terms for Incidence of TBI From RTI

A series of 4 search parameters were used in PubMed (1, 2, 4) and PubMed Central (3):

1) “vehicular accident”\textsuperscript{[ti]} OR “traffic accident”\textsuperscript{[ti]}
   Titles: 63; Abstracts reviewed: 50; Full texts reviewed: 8
2) (“vehicular accidents” AND “traumatic brain injury”) OR
Search Terms for TBI Mechanism of Injury and Severity Distribution

-(“epidemiology” [Subheading] OR “Epidemiology” [MeSH] OR epidemiology[tiab] OR epidemiological[tiab] OR population[tiab] OR population-based[tiab] OR incident[tiab] OR prevalence[tiab] OR burden or ratio[tiab] OR DALY [tiab] OR “disability adjusted life year” [tiab] OR YLL [tiab] OR “years of life lost” [tiab] OR YLD [tiab] OR “years lost to disability” [tiab] OR ratio[tiab] OR QALY [tiab] OR “quality adjusted life year” [tiab])

AND

- (“Head Injuries, Penetrating” [MeSH] OR “Head Injuries, Closed” [MeSH] OR “Brain Injuries” [MeSH] OR “Intracranial Hemorrhage, Traumatic” [MeSH] OR brain injury [tiab] OR head injury [tiab])

AND

- (“Africa” [MeSH] OR “Asia” [MeSH] OR “Central America” [MeSH] OR “Developing Countries” [MeSH] OR “Geographical Locations Category” [MeSH] OR “Internationality” [MeSH] OR “Latin America” [MeSH] OR “South America” [MeSH] OR “Dominican Republic” [tiab] OR “Principio” [tiab] OR “Puerto Rico” [tiab] OR “Sao Tome” [tiab] OR “Saudi Arabia” [tiab] OR “Sierra Leone” [tiab] OR “Virgin Islands” [tiab] OR “Afghanistan” [tiab] OR “Africa” [tiab] OR “Albania” [tiab] OR “Algeria” [tiab] OR “America” [tiab] OR “Andorra” [tiab] OR “Angola” [tiab] OR “Antarctica” [tiab] OR “Antigua” [tiab] OR “Arab Emirates” [tiab] OR “Argentina” [tiab] OR “Armenia” [tiab] OR “Aruba” [tiab] OR “Asia” [tiab] OR “Atlantic” [tiab] OR “Australia” [tiab] OR “Austria” [tiab] OR “Azerbaijan” [tiab] OR “Azores Islands” [tiab] OR “Baham” [tiab] OR “Bahrain” [tiab] OR “Bangladesh” [tiab] OR “Barbados” [tiab] OR “Barbuda” [tiab] OR “Bartholomew” [tiab] OR “Barthelemy” [tiab] OR “Belarus” [tiab] OR “Belgium” [tiab] OR “Belize” [tiab] OR “Bengal” [tiab] OR “Benn” [tiab] OR “Bermuda” [tiab] OR “Bhutan” [tiab] OR “Bissau” [tiab] OR “Bolivia” [tiab] OR “Bosnia” [tiab] OR “Botswana” [tiab] OR “Brazil” [tiab] OR “Brunei” [tiab] OR “Bulgaria” [tiab] OR “Burkina Faso” [tiab] OR “Burma” [tiab] OR “Burmese” [tiab] OR “Burundi” [tiab] OR “Cabo Verde” [tiab] OR “Cairns” [tiab] OR “Cambodia” [tiab] OR “Cameroon” [tiab] OR “Canal” [tiab] OR “Cape Verde” [tiab] OR “Cayman Islands” [tiab] OR “Central” [tiab] OR “Chad” [tiab] OR “Chile” [tiab] OR “China” [tiab] OR “Chinese” [tiab] OR “Colombia” [tiab] OR “Comoros” [tiab] OR “Congo” [tiab] OR “Costa Rica” [tiab] OR “Cote” [tiab] OR “Cote d’Ivoire” [tiab] OR “Croatia” [tiab] OR “Cuba” [tiab] OR “Cuban” [tiab] OR “Cyprus” [tiab] OR “Czech Republic” [tiab] OR “Denmark” [tiab] OR “developing country” [tiab] OR “developing nation” [tiab] OR “Djibouti” [tiab] OR “Dominica” [tiab] OR “East” [tiab] OR “East Timor” [tiab] OR “Ecuador” [tiab] OR “Egypt” [tiab] OR “El Salvador” [tiab] OR “Eritrea” [tiab] OR “Estonia” [tiab] OR “Ethiopia” [tiab] OR “Europ” [tiab] OR “Fiji” [tiab] OR “Finland” [tiab] OR “France” [tiab] OR “French Guiana” [tiab] OR “Gabon” [tiab] OR “Gambia” [tiab] OR “Gaza” [tiab] OR “Georgia” [tiab] OR “Germany” [tiab] OR “Ghana” [tiab] OR “Greece” [tiab] OR “Grenada” [tiab] OR “Grenadines” [tiab] OR “Guadeloupe” [tiab] OR “Guatemala” [tiab] OR “Guinea” [tiab] OR “Guyan” [tiab] OR “Haiti” [tiab] OR “Herzegovina” [tiab] OR “Honduras” [tiab] OR “Hungary” [tiab] OR “Iceland” [tiab] OR “income” [tiab] OR “India” [tiab] OR “Indian” [tiab] OR “Indonesia” [tiab] OR “Iran” [tiab] OR “Iraq” [tiab] OR “Ireland” [tiab] OR “Israel” [tiab] OR “Italian” [tiab] OR “Italy” [tiab] OR “Ivory Coast” [tiab] OR “Jamaica” [tiab] OR “Japan” [tiab] OR “Jordan” [tiab] OR “Kazakhstan” [tiab] OR “Kenya” [tiab] OR “Kiribati” [tiab] OR “Kitts” [tiab] OR “Korea” [tiab] OR “Kosovar” [tiab] OR “Kosovo” [tiab] OR “Kuwait” [tiab] OR “Kyrgyz” [tiab] OR “Laos” [tiab] OR “Latvia” [tiab] OR “Lebanon” [tiab] OR “Lebanon” [tiab] OR “Lesotho” [tiab] OR “least developed country” [tiab] OR “less developed nation” [tiab] OR “Liberia” [tiab] OR “Libya” [tiab] OR “Liechtenstein” [tiab] OR “Lithuania” [tiab] OR “Lom” [tiab] OR “low income country” [tiab] OR “low income nation” [tiab] OR “Lucia” [tiab] OR “Luxembourg” [tiab] OR “Macedonia” [tiab] OR “Madagascar” [tiab] OR “Madeira Island” [tiab] OR “Malawi” [tiab] OR “Malaysia” [tiab] OR “Maldives” [tiab] OR “Malta” [tiab] OR “Marshall Island” [tiab] OR “Martinique” [tiab] OR “Mauritania” [tiab] OR “Mauritius” [tiab] OR “Mexico” [tiab] OR “Micronesia” [tiab] OR “middle income country” [tiab] OR “middle income nation” [tiab] OR “Moldova” [tiab] OR “Moldova” [tiab] OR “Monaco” [tiab] OR “Mongolia” [tiab] OR “Montenegro” [tiab] OR “Montserrat” [tiab] OR “Morocco” [tiab] OR “Mozambique” [tiab] OR “Myanmar” [tiab] OR “Namibia” [tiab] OR “Nauru” [tiab] OR “Nepal” [tiab] OR “Nevis” [tiab] OR “New Zealand” [tiab] OR “Nicaragua” [tiab] OR “Niger” [tiab] OR “Nigeria” [tiab] OR “North” [tiab] OR “Norway” [tiab] OR “Oman” [tiab] OR “Pacific” [tiab] OR “Pakistan” [tiab] OR “Palau” [tiab] OR “Palestine” [tiab] OR “Panama” [tiab] OR “Paraguay” [tiab] OR “Peru” [tiab] OR “Philippines” [tiab] OR “Poland” [tiab] OR “poor country” [tiab] OR “poor nation” [tiab] OR “Portugal” [tiab] OR “Principality” [tiab] OR “Qatar” [tiab] OR “Romania” [tiab] OR “Russia” [tiab] OR “Rwanda” [tiab] OR “Saint Lucia” [tiab] OR “Saint Vincent” [tiab] OR “Samoa” [tiab] OR “San Marino” [tiab] OR “Sao Tome” [tiab] OR “Senegal” [tiab] OR “Serbia” [tiab] OR “Seychelles” [tiab] OR “Sierra Leone” [tiab] OR “Singapore” [tiab] OR “Slovakia” [tiab] OR “Somalia” [tiab] OR “Sri Lanka” [tiab] OR “South” [tiab] OR “Spain” [tiab] OR “Sri Lanka” [tiab] OR “Sudan” [tiab] OR “Suriname” [tiab] OR “Swaziland” [tiab] OR “Switzerland” [tiab] OR “Syria” [tiab] OR “Taiwan” [tiab] OR “Tajikistan” [tiab] OR “Tanzania” [tiab] OR “Thailand” [tiab] OR “third world country” [tiab] OR “third world nation” [tiab] OR “Timor Leste” [tiab] OR “Timor” [tiab] OR “Togo” [tiab] OR “Tonga” [tiab] OR “Trinidad” [tiab] OR “Tunisia” [tiab] OR “Turkey” [tiab] OR “Turkmenistan” [tiab] OR “Turks” [tiab] OR “Tuvalu” [tiab] OR “Uganda” [tiab] OR “Ukraine” [tiab] OR “under developed country” [tiab] OR “under developed nation” [tiab] OR “United Kingdom” [tiab] OR “United States” [tiab] OR “Uruguay” [tiab] OR “Uzbekistan” [tiab] OR “Vanuatu” [tiab] OR “Vatican” [tiab] OR “Venezuela” [tiab] OR “Viet Nam” [tiab] OR “Vietnam” [tiab] OR “Vincent” [tiab] OR “West” [tiab] OR “West Bank” [tiab] OR “Yemen” [tiab] OR “Zambia” [tiab] OR “Zimbabwe” [tiab])

NOT

- (“Humans” [MeSH] OR “Animals” [MeSH])
References

1. Adekoya N, Majumder R: Fatal traumatic brain injury, West Virginia, 1989–1998. Public Health Rep 119:486–492, 2004

2. Adeleye AO, Olowookere KG, Oluyemi OO: Clinicodemographic profiles and outcomes during first hospital admission of head injury patients in Ikeja, Nigeria. A prospective cohort study. Neuroepidemiology 32:136–141, 2009

3. Aenderl I, Gashaw T, Siebeck M, Mutschler W: Head injury—a neglected public health problem: a four-month prospective study at Jimma University Specialized Hospital, Ethiopia. Ethiop J Health Sci 24:27–34, 2014

4. Agarwal-Harding KJ, Meara JG, Greenberg SLM, Hagander LE, Zurakowski D, Dyer GSM: Estimating the global incidence of femoral fracture from road traffic collisions: a literature review. J Bone Joint Surg Am 97:993–999, 2015

5. Agius S, Ansari S, Zrinzo A: Pattern of head injuries in Malta (EU): a small Mediterranean island. Br J Neurosurg 26:212–215, 2012

6. Agrawal A, Agrawal CS, Kumar A, Lewis O, Malla G, Khatiwada R, et al: Epidemiology and management of paediatric head injury in eastern Nepal. Afr J Paediatr Surg 5:15–18, 2008

7. Agrawal A, Galwankar S, Kapil V, Coronado V, Basavaraju SV, McGuire LC, et al: Epidemiology and clinical characteristics of traumatic brain injuries in a rural setting in Maharashtra, India. 2007–2009. Int J Crit Illn Inj Sci 2:167–171, 2012

8. Agrawal D, Ahmed S, Khan S, Gupta D, Sinha S, Satyarthi GD: Outcome in 2068 patients of head injury: experience at a level 1 trauma centre in India. Asian J Neurosurg 11:143–145, 2016

9. Akama MK, Chindia ML, Macigo FG, Guthua SW: Pattern of maxillofacial and associated injuries in road traffic accidents. East Afr Med J 84:287–295, 2007

10. Al-Habib A, A-Shail A, Alaqeel A, Zamakshary M, Al-Bedah K, Alqunayi M, et al: Causes and patterns of adult traumatic head injuries in Saudi Arabia: implications for injury prevention. Ann Saudi Med 33:351–355, 2013 (Ann Saudi Med 34:91, 2014)

11. Ala-Seppälä H, Heino I, Frantzén J, Takala RSK, Katila AJ, Kyllönen A, et al: Injury profiles, demography and representativeness of patients with TBI attending a regional emergency department. Brain Inj 30:1062–1067, 2016

12. Albrecht JS, Hirshon JM, McCunn M, Bechtold KT, Rao V, Simoni-Wastila L, et al: Increased rates of mild traumatic brain injury among older adults in US emergency departments, 2009–2010. J Head Trauma Rehabil 31:E1–E7, 2016

13. Aldawood AS, Alsultani M, Haddad S, Alqahtani SM, Tamim H, Arabi YM: Trauma profile at a tertiary intensive care unit in Saudi Arabia. Ann Saudi Med 32:498–501, 2012

14. Alhabdan S, Zamakshary M, AlNaimi M, Mandora H, Alhamdan M, Al-Bedah K, et al: Epidemiology of traumatic head injury in children and adolescents in a major trauma center in Saudi Arabia: implications for injury prevention. Ann Saudi Med 33:52–56, 2013

15. Ammaranath JE, Ramanan M, Reagh J, Saekang E, Prasad N, Chaseling R, et al: Epidemiology of head injury: a prospective multicenter study. J Neurotrauma 28:2019–2031, 2011

16. Amsadon EO, Halldorsson JG: Head trauma among children in Reykjavik. Acta Paediatr 84:96–99, 1995

17. Asemota AO, George BP, Bowman SM, Haider AH, Schneider EB: Causes and trends in traumatic brain injury for United States adolescents. J Neurotrauma 30:67–75, 2013

18. Atzema C, Mower WR, Hoffman JR, Holmes JF, Killian AJ, Wolfson AB, et al: Prevalence and prognosis of traumatic intraventricular hemorrhage in patients with blunt head trauma. J Trauma 60:1010–1017, 2006

19. Avesani R, Roncari L, Khansefid M, Formisano R, Boldrini P, Zampolini M, et al: The Italian National Registry of severe acquired brain injury: epidemiological, clinical and functional data of 1469 patients. Eur J Phys Rehabil Med 49:611–618, 2013

20. Bachani AM, Koradia P, Herbert HK, Mogere S, Akungah D, Nyamari J, et al: Road traffic injuries in Kenya: the health burden and risk factors in two districts. Traffic Inj Prev 13 (Suppl 1):24–30, 2012

21. Bahloul M, Chelly H, Ben Hmida M, Ben Hamida C, Ksibi H, Kallel H, et al: Prognosis of traumatic head injury in South Tunisia: a multivariate analysis of 437 cases. J Trauma 57:255–261, 2004

22. Bahloul M, Chelly H, Gargouri R, Dammak H, Kallel H, Ben Hamida C, et al: [Traumatic head injury in children in south Tunisia epidemiology, clinical manifestations and evolution. 454 cases.] Tunis Med 87:28–37, 2009 (Fr)

23. Bajracharya A, Agrawal A, Yam B, Agrawal C, Lewis O: Spectrum of surgical trauma and associated head injuries at a university hospital in eastern Nepal. J Neurosci Rural Pract 1:6–8, 2010

24. Baldo V, Marcolongo A, Floreani A, Majori S, Cristofoletti M, Dal Zotto A, et al: Epidemiological aspect of traumatic brain injury in South Tunisia: a multivariate analysis of 437 cases. Eur J Epidemiol 19:1059–1063, 2003

25. Banthia P, Koirala B, Rauniyar A, Chaudhary D, Kharel T, Khadka SB: An epidemiological study of road traffic accident cases attending emergency department of teaching hospital. J Nepal Med Assoc 45:238–243, 2006

26. Barker-Collo SL, Wilde NJ, Feigin VL: Trends in head injury incidence in New Zealand: a hospital-based study from 1997/1998 to 2003/2004. Neuroepidemiology 32:32–39, 2009

27. Bayreuther J, Wagener S, Woodford M, Edwards A, Lecky F, Bouamra O, et al: Paediatric trauma: injury pattern and mortality in the UK. Arch Dis Child Educ Pract Ed 94:37–41, 2009

28. Bener A, Abdul Rahman YS, Abdel Aleem EY, Khalid MK: Trends and characteristics of head and neck injury from falls: a hospital based study, Qatar. Sultan Qaboos Univ Med J 11:244–251, 2011

29. Bener A, Omar AOK, Ahmad AE, Al-Mulla FH, Abdul Rahman YS: The pattern of traumatic brain injuries: a country undergoing rapid development. Brain Inj 24:74–80, 2010

30. Berry JG, Jamieson LM, Harrison JE: Head and traumatic brain injuries among Australian children, July 2000–June 2006. Inj Prev 16:198–202, 2010
traumatic brain injury-related hospitalization in very young children—15 states, 1999. J Head Trauma Rehabil 21:537–543, 2006.

72. El-Matbouly M, El-Menyar A, Al-Thani H, Tuma M, El-Hennawy H, AbdullRahman H, et al: Traumatic brain injury in Qatar: age matters—insights from a 4-year observational study. Sci World J 2013:354920–354926, 2013.

73. Emanuelson I, v Wendt L: Epidemiology of traumatic brain injury in children and adolescents in south-western Sweden. Acta Paediatr 86:730–735, 1997.

74. Emegwu J: Epidemiological patterns of head injury in a newly established neurosurgical service: one-year prospective study. Afr J Med Sci 37:383–388, 2008.

75. Emejulu JKC: Epidemiological patterns of head injury in Denmark 1979–1996. A national study of incidence and mortality. Eur J Epidemiol 17:437–442, 2001.

76. Falk AC, Klang B, Paavonen EJ, von Wendt L: Current incidence and management of children with traumatic head injuries: the Stockholm experience. Dev Neurorehabil 10:49–55, 2007 (Erratum in Dev Neurorehabil 10:267, 2007)

77. Feigen VL, Forouzanfar MH, Krishnamurthi R, Mensah GA, Connor M, Bennett DA, et al: Global and regional burden of stroke during 1990–2010: findings from the Global Burden of Disease Study 2010. Lancet 383:245–254, 2014.

78. Fekih Hassen A, Zayani MC, Friaa M, Trifa M, Ben Khalifa K, Kahan M, et al: Incidence of traumatic brain injury in New Zealand: a population-based study. Lancet Neurol 12:53–64, 2013.

79. Feinberg M, Mai J, Ecklund J: Neurosurgical management of delayed presentation of epidural hematomas: the Stockholm experience. Dev Neurorehabil 10:49–55, 2007 (Erratum in Dev Neurorehabil 10:267, 2007)

80. Firth RJ: Epidemiology of head injuries in Denmark 1979–1996. A national study of incidence and mortality. Eur J Epidemiol 17:437–442, 2001.

81. Fischinger R, Woinseck D: Present status of neurosurgical trauma in Germany. World J Surg 25:1221–1223, 2001.

82. Fletcher AE, Khalid S, Mallonee S: The epidemiology of severe traumatic brain injury among persons 65 years of age and older in Oklahoma, 1992–2003. Brain Inj 21:691–699, 2007.

83. Frohlich S, Johnson P, Moriarty J: Prevalence, management and outcomes of traumatic brain injury patients admitted to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

84. Fu TS, Jing R, Fu WW, Cusimano MD: Epidemiological trends of traumatic brain injury identified in the emergency department in a publicly-insured population, 2002–2010. PLoS One 11:e0145469, 2016.

85. Fuller G, Bouamra O, Woodford M, Jenks T, Patel H, Coats TJ, et al: Temporal trends in head injury outcomes from 2003 to 2009 in England and Wales. Br J Neurosurg 25:414–421, 2011.

86. Gabella B, Hoffman RE, Marine WW, Stallones L: Urban and rural traumatic brain injuries in Colorado. Ann Epidemiol 7:202–217, 1997.

87. Gisladottir EH, Karason S, Sigvaldason K, Ulfarsson E, Mogensen B: [Visits to an emergency department due to head injuries.] Laeknabladid 100:331–335, 2014 (Icelandic).

88. Gordon KE, Dooley JM, Wood EP: Descriptive epidemiology of concussion. Pediatr Neurol 34:376–378, 2006.

89. Guerrero JL, Thurman DJ, Snieszek JE: Emergency department visits associated with traumatic brain injury: United States, 1995–1996. Brain Inj 14:181–186, 2000.

90. Gupta S, Iv V, Sam N, Vuthy D, Klaric K, Shrimp MG, et al: Impact of helmet use on severity of epidural hematomas in Cambodia. World Neurosurg 100:267–270, 2017.

91. Halldorsson JG, Flekkoy KM, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early management outcome of paediatric head trauma: one-year prospective study. Neger J Clin Pract 13:276–279, 2010.

92. Halldorsson JG, Flekkoy KM, Gudmundsson KR, Arnkelsson GB, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early management outcome of paediatric head trauma: one-year prospective study. Neger J Clin Pract 13:276–279, 2010.

93. Halldorsson JG, Flekkoy KM, Arnkelsson GB, Arnarson EO: Urban-rural differences in traumatic brain injuries among persons 65 years of age and older in Oklahoma, 1992–2003. Brain Inj 21:691–699, 2007.

94. Hartholt KA, Van Lieshout EMM, Polinder S, Panneman MJM, Van der Cammen TJM, Patka P: Rapid increase in hospitalizations resulting from fall-related traumatic head injuries among Australian youth and young adults, 2000–2009. World J Surg 30:630–634, 2013 (Spain).

95. Hamilton M, Mrazik M, Johnson DW: Incidence of delayed presentation of epidural hematomas to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

96. Hartsholt KA, Van Lieshout EMM, Polinder S, Panneman MJM, Van der Cammen TJM, Patka P: Rapid increase in hospitalizations resulting from fall-related traumatic head injury in older adults in The Netherlands 1986–2008. J Neurotrauma 28:739–744, 2011.

97. Harvey LA, Close JT: Traumatic brain injury in older adults: characteristics, causes and consequences. Injury 43:1821–1826, 2012.

98. Herrera PB, Johnson P, Moriarty J: Prevalence, management and outcomes of traumatic brain injury patients admitted to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

99. Herrera PB, Johnson P, Moriarty J: Prevalence, management and outcomes of traumatic brain injury patients admitted to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

100. Halldorsson JG, Flekkoy KM, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early management outcome of paediatric head trauma: one-year prospective study. Neger J Clin Pract 13:276–279, 2010.

101. Halldorsson JG, Flekkoy KM, Arnkelsson GB, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early management outcome of paediatric head trauma: one-year prospective study. Neger J Clin Pract 13:276–279, 2010.

102. Halldorsson JG, Flekkoy KM, Arnkelsson GB, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early management outcome of paediatric head trauma: one-year prospective study. Neger J Clin Pract 13:276–279, 2010.

103. Halldorsson JG, Flekkoy KM, Arnkelsson GB, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early management outcome of paediatric head trauma: one-year prospective study. Neger J Clin Pract 13:276–279, 2010.

104. Hamilton M, Mrazik M, Johnson DW: Incidence of delayed presentation of epidural hematomas to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

105. Hamilton M, Mrazik M, Johnson DW: Incidence of delayed presentation of epidural hematomas to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

106. Hamilton M, Mrazik M, Johnson DW: Incidence of delayed presentation of epidural hematomas to an Irish intensive care unit. Ir J Med Sci 180:423–427, 2011.

107. Hartholt KA, Van Lieshout EMM, Polinder S, Panneman MJM, Van der Cammen TJM, Patka P: Rapid increase in hospitalizations resulting from fall-related traumatic head injury in older adults in The Netherlands 1986–2008. J Neurotrauma 28:739–744, 2011.

108. Harvey LA, Close JT: Traumatic brain injury in older adults: characteristics, causes and consequences. Injury 43:1821–1826, 2012.
109. Hawley C, Wilson J, Hickson C, Mills S, Ekeocha S, Sakr M: Epidemiology of paediatric minor head injury: comparison of injury characteristics with indices of multiple deprivation. Injury 44:1855–1861, 2013

110. Hawley CA, Ward AB, Long J, Owen DW, Magnay AR: Prevalence of traumatic brain injury amongst children admitted to hospital in one health district: a population-based study. Injury 34:256–260, 2003

111. Heim C, Bosissio F, Roth A, Bloch J, Borens O, Daniel RT, et al: Is trauma in Switzerland any different today? Epidemiology and patterns of injury in major trauma—a 5-year review from a Swiss trauma center. Swiss Med Wkly 144:w13958, 2014

112. Heskestad B, Baardsen R, Helseth E, Rommer B, Waterlo K, Ingebrigtsen T: Incidence of hospital referred head injuries in Norway: a population based survey from the Stavanger region. Scand J Trauma Resusc Emerg Med 17:6, 2009

113. Hu J, Ugilikweneza B, Meyer K, Lad SP, Boakye M: Trend and geographic analysis for traumatic brain injury mortality and cost based on MarketScan database. J Neurotrauma 30:1755–1761, 2013

114. Idowu OE, Akinbo O: Neurotrauma burden in a tropical urban congregation level I trauma centre. Injury 45:1717–1721, 2014

115. Ingebrigtsen T, Mortensen K, Rommer B: The epidemiology of hospital-referred head injury in northern Norway. Neuroepidemiology 17:139–146, 1998

116. Institute for Health Metrics and Evaluation: Global Burden of Disease Study 2015: Incidence, Prevalence, and Years Lived with Disability 1990–2015. Seattle: Institute for Health Metrics and Evaluation, 2016

117. İskh HS, Bostancı U, Yıldız O, Ozdemir C, Gökya A: [Retrospective analysis of 954 adult patients with head injury: an epidemiological study.] Ulus Travma Acil Cerrahi Derg 17:46–50, 2011 (Turkish)

118. İskh HS, Gökya A, Yıldız O, Bostancı U, Ozdemir C: [Pediatric head injuries, retrospective analysis of 851 patients: an epidemiological study.] Ulus Travma Acil Cerrahi Derg 17:166–172, 2011 (Turkish)

119. Jacobsson LJ, Westerberg M, Lexell J: Demographics, injury characteristics and outcome of traumatic brain injuries in northern Sweden. Acta Neurol Scand 116:300–306, 2007

120. Jager TE, Weiss HB, Cohen JH, Pepe TR: Traumatic brain injuries evaluated in U.S. emergency departments, 1992–1994. Acad Emerg Med 7:134–140, 2000

121. Jagnoor J, Keay L, Ganguli A, Dandona R, Thakur JS, Boufous S, et al: Fall related injuries: a retrospective medical review study in North India. Injury 43:1996–2000, 2012

122. Jaja BNR, Eghwrudjakpor PO: Effect of demographic and injury etiological factors on intensive care unit mortality after severe head injury in a low middle income country. Ann Afr Med 13:204–209, 2014

123. Jamieson LM, Roberts-Thomas KF: Hospitalized head injuries among older people in Australia, 1998/1999 to 2004/2005. Inj Prev 13:243–247, 2007

124. Javouhey E, Guérin AC, Chiron M: Incidence and risk factors of severe traumatic brain injury resulting from road accidents: a population-based study. Accid Anal Prev 38:225–233, 2006

125. Ji C, Duan L, Wang L, Wu C, Wang Y, Er Y, et al.: [Study on head injuries through data from the National Injury Surveillance System of China, 2013.] Zhonghua Liu Xing Bing Xue Za Zhi 36:360–363, 2013 (Chinese)

126. Jiang YJ, Feng H, Fu Z, Guo-yi G, Wei-ping L, Wei-guo L, et al: Violent head trauma in China: report of 2254 cases. Surg Neurol 68 (Suppl 2):S2–S5, 2007

127. Kalanithi P, Schubert RD, Lad SP, Harris OA, Boakye M: Hospital costs, incidence, and inhospital mortality rates of traumatic subdural hematoma in the United States. J Neurosurg 115:1013–1018, 2011

128. Kamal VK, Agrawal D, Pandey RM: Epidemiology, clinical characteristics and outcomes of traumatic brain injury: evidences from integrated level 1 trauma center in India. J Neurosci Rural Pract 7:515–525, 2016

129. Kaptigau WM, Ke L, Rosenfeld JV: Trends in traumatic brain injury outcomes in Port Moresby General Hospital from January 2003 to December 2004. P N G Med J 50:50–57, 2007

130. Karibe H, Kameyama M, Kawase M, Hirano T, Kawaguchi T, Tomina T: [Epidemiology of chronic subdural hematomas.] No Shinkei Geka 39:1149–1153, 2011 (Jpn)

131. Katsaragakis S, Drimousis PG, Toutouzas K, Stefanatou M, Larentzakis A, Theodoraki ME, et al: Traumatic brain injury in Greece: report of a countrywide registry. Brain Inj 24:871–876, 2010

132. Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF, Sinfl S: A population-based study of inflicted traumatic brain injury in young children. JAMA 290:621–626, 2003

133. Kelly P, John S, Vincent AL, Reed P: Abusive head trauma and accidental head injury: a 20-year comparative study of referrals to a hospital child protection team. Arch Dis Child 100:1123–1130, 2015

134. Khan A, Prince M, Brayne C, Prima AM: Lifetime prevalence and factors associated with head injury among older people in low and middle income countries: a 10/66 study. PLoS One 10:e0132229, 2015

135. Kim HB, Kim DK, Kwak YY, Shin SD, Song KJ, Lee SC, et al: Epidemiology of traumatic head injury in Korean children. J Korean Med Sci 27:437–442, 2012

136. King J, Haddock G: Neonatal head injuries revisited. Scott Med J 54:34–36, 2009

137. Koepsell TD, Rivara FP, Vavilala MS, Wang J, Temkin N, Jaffe KM, et al: Incidence and descriptive epidemiologic features of traumatic brain injury in King County, Washington. Pediatrics 128:946–954, 2011

138. Kool B, Chelimo C, Ameratunga S: Head injury incidence and mortality in New Zealand over 10 Years. Neuroepidemiology 41:189–197, 2013

139. Kool B, Raj N, Wainiqolo I, Kafafo B, McCaig E, Ameratunga S: Hospitalised and fatal head injuries in Viti Levu, Fiji: findings from an island-wide trauma registry (TRIP 4). Neuroepidemiology 38:179–185, 2012

140. Koskinen E, Alaranta H: Traumatic brain injury etiology and accidental head injury among older people in low and middle income countries: a 10/66 study. Brain Inj 22:205–214, 2008

141. Kramer AH, Zygun DA, Doig CJ, Zuege DJ: Incidence of neurologic death among patients with brain injury: a cohort study in a Canadian health region. CMAJ 185:E838–E845, 2013

142. Krause JF, Fife D, Cox P, Ramstein K, Conroy C: Incidence, severity, and external causes of pediatric brain injury. Am J Dis Child 140:687–693, 1986

143. Krause M, Richards S: Prevalence of traumatic brain injury and access to services in an undergraduate population: a pilot study. Brain Inj 28:1301–1310, 2014

144. Lagbas C, Bazargan-Hejazi S, Shaheen M, Kermah D, Pan D: Traumatic brain injury related hospitalization and mortality in California. BioMed Res Int 2013:143092–143099, 2013

145. Lagolago W, Theadom A, Fairbairn-Dunlop P, Ameratunga S, Dowell A, McPherson KM, et al: Traumatic brain injury and cost based on MarketScan database. JAMA 290:621–626, 2003

146. Lambo et al: Violent head trauma among older people in Australia, 1998/1999 to 2004/2005. Inj Prev 13:243–247, 2007

147. Langlois JA, Kegler SR, Butler JA, Gotsch KE, Johnson RL, Reichard AA, et al: Traumatic brain injury-related

M. C. Dewan et al.
hospital discharges. Results from a 14-state surveillance system. 1997. MMWR Surveill Summ 52:1–20, 2003
147. Lasry O, Dudley RW, Fuhrer R, Torrie J, Carlin R, Marcoux J: Traumatic brain injury in a rural indigenous population in Canada: a community-based approach to surveillance. CMAJ Open 4:E249–E259, 2016
148. Le Roux AA, Nadvi SS: Acute extradural haematoma in the elderly. Br J Neurosurg 21:16–20, 2007
149. Lee KS: Estimation of the incidence of head injury in Korea: an approximation based on national traffic accident statistics. J Korean Med Sci 16:342–346, 2001
150. Leibson CL, Brown AW, Ransom JE, Diehl NN, Perkins PJ, Mandrekar J, et al: Incidence of traumatic brain injury across the full disease spectrum: a population-based medical record review study. Epidemiology 22:836–844, 2011
151. Li Y, Gu J, Zhou J, Xia X, Wang K, Zheng X, et al: The epidemiology of traumatic brain injury in civilian inpatients of Chinese Military Hospitals, 2001–2007. Brain Inj 29:981–988, 2015
152. Lin CM, Li CY: Assessment of medical resource utilization for Taiwanese children hospitalized for intracranial injuries. Injury 45:690–693, 2014
153. Maegle M, Engel D, Bouillon B, Lefering R, Fach H, Raum M, et al: Incidence and outcome of traumatic brain injury in an urban area in Western Europe over 10 years. Eur Surg Res 39:372–379, 2007
154. Maier D, Njoku I Jr, Schmutzhard E, Dharsee J, Doppler M, Härtl R, et al: Traumatic brain injury in a rural and an urban Tanzanian hospital—a comparative, retrospective analysis based on computed tomography. World Neurosurg 81:478–482, 2014
155. Majdan M, Mauritz W, Brazinova A, Rusnak M, Leitgeb J, Janciak I, et al: Severity and outcome of traumatic brain injuries (TBI) with different causes of injury. Brain Inj 25:797–805, 2011
156. Majdan M, Mauritz W, Rusnak M, Brazinova A, Rehorcikova V, Leitgeb J: Long-term trends and patterns of fatal traumatic brain injuries in the pediatric and adolescent population of Austria in 1980–2012: analysis of 33 years. J Neurotrauma 31:1046–1055, 2014
157. Majdan M, Rusnak M, Brazinova A, Mauritz W: Severity, causes and outcomes of traumatic brain injuries occurring at different locations: implications for prevention and public health. Cent Eur J Public Health 23:142–148, 2015
158. Marchio PS, Previgliano IJ, Goldini CE, Murillo-Cabezas F: [Head injury in Buenos Aires city: a prospective, population-based, epidemiologic study.] Neurocirugia (Astr) 17:141–2006, 2003 (Spanish)
159. Marlow R, Mytton J, Maconochie IK, Taylor H, Lyttle MD: Trends in admission and death rates due to paediatric head injury in England, 2000–2011. Arch Dis Child 100:i136–i140, 2015
160. Martins ET, Linhares MN, Sousa DS, Schroeder HK, Meinerz J, Rigo LA, et al: Mortality in severe traumatic brain injury: a multivariate analysis of 748 Brazilian patients from Florianópolis City. J Trauma 67:855–90, 2009
161. Masson F, Thicoipe M, Aye P, Mokni T, Senjean P, Schmitt V, et al: Epidemiology of severe brain injuries: a prospective population-based study. J Trauma 51:481–489, 2001
162. Mauritz W, Brazinova A, Majdan M, Leitgeb J: Epidemiology of traumatic brain injury in Austria. Wien Klin Wochenschr 126:42–52, 2014
163. Mauritz W, Brazinova A, Majdan M, Leitgeb J: Hospital admissions for traumatic brain injury of Austrian residents vs. of visitors to Austria. Brain Inj 28:1295–1300, 2014
164. Mauritz W, Brazinova A, Majdan M, Rehorcikova V, Leitgeb J: Deaths due to traumatic brain injury in Austria between 1980 and 2012. Brain Inj 28:1096–1101, 2014
165. McKinlay A, Grace RC, Horwood LJ, Ferguson DM, Ridder EM, MacFarlane MR: Prevalence of traumatic brain injury among children, adolescents and young adults: prospective evidence from a birth cohort. Brain Inj 22:175–181, 2008
166. Meehan WP III, Mannix R: Pediatric concussions in United States emergency departments in the years 2002 to 2006. J Pediatr 157:889–893, 2010
167. Melo JRT, de Santana DLP, Pereira JLB, Ribeiro TF: [Traumatic brain injury in children and adolescents at Salvador City, Bahia, Brazil.] Arq Neuropsiquiatr 64:994–996, 2006 (Portuguese)
168. Meng X, Shi B: Traumatic brain injury patients with a Glasgow Coma Scale score of ≤8, cerebral edema, and/or a basal skull fracture are more susceptible to developing hyponatremia. J Neurosurg Anesthesiol 28:21–26, 2016
169. Miekis I, Cyzyz M, Tykocki T, Kaczmarczyk J, Zaluski R, Latka D: Traumatic brain injury in Poland from 2009–2012: a national study on incidence. Brain Inj 30:79–82, 2016
170. Mishra B, Sinha Mishra ND, Sukhla S, Sinha A: Epidemiological study of road traffic accident cases from Western Nepal. Indian J Community Med 35:115–121, 2010
171. Mitra B, Cameron P, Butt W: Population-based study of paediatric head injury. J Paediatr Child Health 43:154–159, 2007
172. Mitra B, Cameron PA, Butt W, Rosenfeld JV: Children or young adults? A population-based study on adolescent head injury. ANZ J Surg 76:343–350, 2006
173. Mohler D, Shameer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 4:1–9, 2015
174. Moore L, Evans D, Hameed SM, Yanchar NL, Stelfox HT, Simons R, et al: Mortality in Canadian trauma systems: a multicenter cohort study. Ann Surg 265:212–217, 2017
175. Moorin R, Miller TR, Hendrie D: Population-based incidence and 5-year survival for hospital-admitted traumatic brain and spinal cord injury, Western Australia, 2003–2008. J Neurol 261:1726–1734, 2014
176. Morisse E, Favarel-Garrigues JF, Couadau E, Mikulski M, Xavier L, Ryckwaert Y, et al: Incidence of hospital-admitted severe traumatic brain injury and in-hospital fatality rates in a Pacific Island country: a 5-year retrospective study. Brain Inj 28:1436–1440, 2014
177. Mosenthal AC, Lavery RF, Addis M, Kaul S, Ross S, Marber R, et al: Isolated traumatic brain injury: age is an independent predictor of mortality and early outcome. J Trauma 52:907–911, 2002
178. Murray GD, Teasdale GM, Braakman R, Cohadon F, Dearden M, Iannotti F, et al: The European Brain Injury Consortium survey of head injuries. Acta Neurochir (Wien) 141:223–236, 1999
179. Muyembe VM, Suleman N: Head injuries at a Provincial General Hospital in Kenya. East Afr Med J 76:200–205, 1999
180. Myburgh JA, Cooper DJ, Finfer SR, Venkatesh B, Jones D, Higgins A, et al: Epidemiology and 12-month outcomes from traumatic brain injury in Australia and New Zealand. J Trauma 64:854–862, 2008
181. Møyer MC, Grøgaard JB, Dyb GA, Sandvik L, Nordhov M: Traumatic head injury in infants and toddlers. Br J Neurosurg 854–862, 2008
182. Nakamura N, Yamaura A, Shigemori M, Ogawa T, Tokutomi T, Ono J, et al: Final report of the Japan Neurotrauma Data Bank project 1998–2001: 1,002 cases of traumatic brain injury. Neurol Med Chir (Tokyo) 46:567–574, 2006
183. Nigrovic LE, Lee CK, Hoyle J, Stanley RM, Gorelick MH,
220. Sethi M, Heidenberg J, Wall SP, Ayoung-Chee P, Slaughter D, Levine DA, et al: Bicycle helmets are highly protective against traumatic brain injury within a dense urban setting. Injury 46:2483–2490, 2015

221. Shao J, Zhu H, Yao H, Stallones L, Yeates K, Wheeler K, et al: Characteristics and trends of pediatric traumatic brain injuries treated at a large pediatric medical center in China, 2002–2011. PLoS One 7:e51634–e51637, 2012

222. Shekhar C, Gupta LN, Premsgar IC, Sinha M, Kishore J: An epidemiological study of traumatic brain injury cases in a trauma centre of New Delhi (India). J Emerg Trauma Shock 8:131–139, 2015

223. Shi HY, Hwang SL, Lee IC, Chen JT, Lee KT, Lin CL: Trends and outcome predictors after traumatic brain injury surgery: a nationwide population-based study in Taiwan. J Neurosurg 121:1323–1330, 2014

224. Shi J, Xiang H, Wheeler K, Smith GA, Stallones L, Groner J, et al: Costs, mortality likelihood and outcomes of hospitalized US children with traumatic brain injuries. Brain Inj 23:602–611, 2009

225. Shimoda K, Maeda T, Tado M, Yoshino A, Katayama Y, Bullock MR: Outcome and surgical management for geriatric traumatic brain injury: analysis of 888 cases registered in the Japan Neurotrauma Data Bank. World Neurosurg 82:1300–1306, 2014

226. Shivaji T, Lee A, Dougall N, McMillan T, Stark C: The epidemiology of hospital treated traumatic brain injury in Scotland. BMC Neurol 14:2, 2014

227. Shukri AA, Bersnev VP, Riabukha NP: The epidemiology of brain injury and the organization of health care to victims in Aden (Yemen). Zh Vopr Neurokhir Im N N Burdenko:40–42, 2006 (Russian)

228. Siman-Tov M, Radomislensky I, Knoller N, Bahouth H, Slesak G, Inthalath S, Wilder-Smith A, Barennes H: Road traffic injuries at Kigali University Central Teaching Hospital in Rwanda. Trop Med Int Health 82:1300–1306, 2014

229. Staton CA, Msilanga D, Kiwango G, Vissoci JR, de Andrade L, Lester R, et al: A prospective registry evaluating the epidemiology and clinical care of traumatic brain injury in New Zealand: incidence, prevalence and disability-adjusted life years. Neuroepidemiology 44:255–261, 2015

230. Suominen JS, Pakarinen MP, Kiihräinen S, Impinen A, Vartiainen E, Helenius I: In-hospital treated pediatric injuries are increasing in Finland—a population based study between 1997 and 2006. Scand J Surg 100:129–135, 2011

231. Sampaio L, Madzhaia M: Epidemiology of cranio-cerebral injuries in emergency medical services practice. Pol Przegl Chir 83:646–651, 2011

232. Tabish A, Lone NA, Afzal WM, Salam A: The incidence and severity of injury in children hospitalised for traumatic brain injury in Kashmir. Injury 37:410–415, 2006

233. Tait RJ, Anstey KJ, Butterworth P: Incidence of self-reported brain injury and the relationship with substance abuse: findings from a longitudinal community survey. BMC Public Health 10:171, 2010

234. Tasker RC, Fleming TJ, Young AE, Morris KP, Parslow RC: Severe head injury in children: intensive care unit activity and mortality in England and Wales. Br J Neurosurg 25:68–77, 2011

235. Tasker RC, Morris KP, Forsyth RJ, Hawley CA, Parslow RC: Severe head injury in children: emergency access to neurosurgery in the United Kingdom. Emerg Med J 23:519–522, 2006

236. Tsai WC, Chiu WT, Chou HY, Choy CS, Hung CC, Tsai SH: Pediatric traumatic brain injuries in Taiwan: an 8-year study. J Clin Neurosci 11:126–129, 2004

237. Twagirayezu E, Teteli R, Bonane A, Rugwizangoga E, Theadom A, Dowell A, et al: Burden of traumatic brain injury in New Zealand: incidence, prevalence and disability-adjusted life years. Neuroepidemiology 44:255–261, 2015

238. Umerani MS, Abbas A, Sharif S: Traumatic brain injuries: trends and outcome predictors after traumatic brain injury in Mulago National Referral Hospital in Uganda. World Neurosurg 83:269–277, 2015

239. Udoh DO, Adeyemo AA: Traumatic brain injuries in children: a hospital-based study in Nigeria. Afr J Paediatr Surg 10:154–159, 2013

240. Umreni MS, Abbas A, Sharif S: Traumatic brain injuries: experience from a tertiary care centre in Pakistan. Turk Neurosurg 24:19–24, 2014

241. Vatsnami S, Ranga A, Fajr R: Neuropsychiatric problems after traumatic brain injury: unraveling the silent epidemic. Psychiatr Clin Pract 12:129–139, 2015

242. Ventes G, Kolk A, Tuulemaa E, E usur E, Sakanmaa M, Toomv T: The incidence of childhood traumatic brain injury in Tartu and Tartu County in Estonia. World J Surg 30:129–135, 2011

243. Vincent V, Kalt K, Vali M, Vaiinmaa M, Talvik T: The incidence of childhood traumatic brain injury in Tartu and Tartu County in Estonia. Neuroepidemiology 30:20–24, 2008

244. von Elm E, Osterwalder JJ, Graber C, Schoettker P, Stocker R, Zanger P, et al: Severe traumatic brain injury in Switzerland: feasibility and first results of a cohort study. Swiss Med Wkly 138:327–334, 2008

245. Wagner AK, Sasser HC, Hammond FM, Wiersciswski D, Alexander J: Intentional traumatic brain injury: epidemiol-
ogy, risk factors, and associations with injury severity and mortality. J Trauma 49:404–410, 2000

257. Wald er B, Haller G, Rebetez MML, Delhumeau C, Bottequin E, Schoettker P, et al: Severe traumatic brain injury in a high-income country: an epidemiological study. J Neurotrauma 30:1934–1942, 2013

258. Winqvist S, Lehtilah I, Jokelainen J, Luukinen H, Hillbom M: Traumatic brain injuries in children and young adults: a birth cohort study from northern Finland. Neuroepidemiology 29:136–142, 2007

259. Wong JC, Linn KA, Shinohara RT, Mateen FJ: Traumatic brain injury in Africa in 2050: a modeling study. Eur J Neurol 23:382–386, 2016

260. World Health Organization: World Health Statistics 2015. (http://www.who.int/gho/publications/world_health_statistics/2015/en/) [Accessed January 10, 2018]

261. Yates PJ, Williams WH, Harris A, Round A, Jenkins R: An epidemiological study of head injuries in a UK population attending an emergency department. J Neurol Neurosurg Psychiatry 77:699–701, 2006

262. Younis R, Younis M, Hamidi S, Musmar M, Mawson AR: Causes of traumatic brain injury in patients admitted to Rafidia, Al-Ittihad and the specialized Arab hospitals, Palestine, 2006–2007. Brain Inj 25:282–291, 2011

263. Yousefzadeh Chabok S, Ramezani S, Kouchakinejad L, Saneei Z: Epidemiology of pediatric head trauma in Guilan. Arch Trauma Res 1:19–22, 2012

264. Zhang AL, Sing DC, Rugg CM, Feeley BT, Senter C: The rise of concussions in the adolescent population. Orthop J Sports Med 4:2325967116662458, 2016

265. Zhao YD, Wang W: Neurosurgical trauma in People’s Republic of China. World J Surg 25:1202–1204, 2001

266. Zhu H, Gao Q, Xia X, Xiang J, Yao H, Shao J: Clinically-important brain injury and CT findings in pediatric mild traumatic brain injuries: a prospective study in a Chinese reference hospital. Int J Environ Res Public Health 11:3493–3506, 2014

267. Zubovic A, Shamdasani S, Fogarty EE, Moore D, Dowling F: Minor head injuries in children. Ir Med J 99:121–123, 2006

268. Zuckerman SL, Yengo-Kahn AM, Buckley TA, Solomon GS, Sills AK, Kerr ZY: Predictors of postconcussion syndrome in collegiate student-athletes. Neurosurg Focus 40(4):E13, 2016

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Conception and design: Dewan, Rattani. Acquisition of data: Rattani, Baticulon, Hung, Punchak. Analysis and interpretation of data: Dewan, Rattani, Gupta. Drafting the article: Dewan. Critically revising the article: Dewan, Rattani, Gupta, Baticulon, Agrawal, Adeleye, Shrime, Rubiano, Rosenfeld, Park. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Dewan. Statistical analysis: Rattani, Gupta. Administrative/technical/material support: Rattani. Study supervision: Dewan, Shrime, Park.

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