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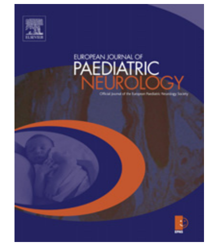

Original article

The incidence of traumatic brain injury in young people in the catchment area of the University Hospital Rotterdam, The Netherlands

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ABSTRACT

Background: Traumatic brain injury (TBI) is in the developed countries the most common cause of death and disability in childhood.
Aim: The purpose of this study is to estimate the incidence of TBI for children and young people in an urbanised region of the Netherlands and to describe relevant characteristics of this group.
Methods: Patients, aged 1 month - 24 years who presented with traumatic brain injury at the Erasmus University Hospital (including the Sophia Children's Hospital) in 2007 and 2008 were included in a retrospective study. Data were collected by means of diagnosis codes and search terms for TBI in patient records. The incidence of TBI in the different referral areas of the hospital for standard, specialised and intensive patient care was estimated.
Results: 472 patients met the inclusion criteria. The severity of the Injury was classified as mild in 342 patients, moderate in 50 patients and severe in 80 patients. The total incidence of traumatic brain injury in the referral area of the Erasmus University Hospital was estimated at 113.9 young people per 100.000. The incidence for mild traumatic brain injury was estimated at 104.4 young people, for moderate 6.1 and for severe 3.4 young people per 100.000.
Conclusion: The ratio for mild, moderate and severe traumatic brain injury in children and young people was 33.7–1.8–1.In the mild TBI group almost 17% of the patients reported sequelae. The finding that 42% of them had a normal brain CT scan at admission underwrites the necessity of careful follow up of children and young people with mild TBI.

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1. Introduction

Traumatic brain injury (TBI) is in the developed countries an important public health problem and the most common cause of death and disability in childhood.[1,2] Epidemiological data on TBI in the Netherlands are out of date and incomplete.[3] Studies on the incidence of TBI are difficult to compare because they are based on different definitions and inclusion criteria.[4] They may include the total population,[1,3] or children 0–14 years.[5–8] Some studies only estimate the incidence rate for hospitalised children,[6–10] or use strict criteria for TBI.[11] In a previous Dutch study, the annual incidence rate of traumatic skull and brain injuries was estimated at 836 people per 100.000.[3] In this study 242.4 per 100.000 people were children aged <15 years. More exact figures are urgently needed in order to be able to estimate the need of post TBI intervention facilities, both at the level of education and rehabilitation care. In recent years, it has become clear that especially in the group of children, adolescents and young adults with mild TBI acquired cognitive deficits are not always diagnosed.[12] Diagnosis of neuropsychological deficits after brain injury is important because they have negative influence on emotional, behavioural and social functioning. Consequently, they may impair school and professional careers as well as quality of life of the victims.[13–16] Plasticity of the brain is an important concept in infants and children, which to a certain extent enables them to reorganise and recover after injury.[17] More recently, evidence arose that a proactive community based intervention program ameliorates the integration of children with TBI in the community.[18] It is necessary to be aware of the number of young people with TBI who would be eligible for entering such a program before such a proactive approach is introduced in the Netherlands. The purpose of this study is to estimate the annual incidence of TBI for young people in an urbanised region of the Netherlands and to describe relevant characteristics of this group such as severity of brain injury, patient characteristics and present policy concerning clinical observation and follow-up.

2. Methods

We retrospectively identified children and young people, aged 1 month–24 years with traumatic injury to the skull who presented in 2007 and 2008 at the Erasmus University Hospital Rotterdam, which includes the Sophia Children's Hospital. We have chosen this age range because in the Netherlands, paediatric rehabilitation specialists offer cognitive rehabilitation programs to children, adolescents and young people in transition to adulthood up to the age of 24 years. We searched the hospital medical database by diagnosis codes (DBC-codes, in Dutch: diagnose-behandel-combinatie) and by search terms in the patient reports for TBI. DBC-codes are used in the Netherlands to specify finances in health care. They are derived from the International Statistical Classification of Diseases and Related Health Problems (ICD-codes).[19] In the patient reports, a computer-based search strategy was performed with the following terms: minor head injury, traumatic brain injury, concussion, skull/brain trauma, neurological trauma. Two additional databases were consulted to check the completeness of the data collection for TBI patients i.e. Sophia emergency ward database in which the reason for visiting the emergency department is prospectively noted and the Sophia intensive care unit database. This study was approved by the medical ethical committee (METC) of our hospital.

2.1. *Inclusion criteria*

We identified all patients aged 1 month–24 years (i.e. young people) who presented with traumatic injury to the skull and subdivided them in the following categories: 1. injury to the skull without signs and/or symptoms of brain injury at presentation. 2. Injury to the skull with signs and/or symptoms of brain injury at presentation. Criteria for brain injury were a history or observed loss of consciousness after a head trauma, and/or post traumatic amnesia, and/or abnormalities at neurological examination, and/or acute traumatic abnormalities on scan images of the brain. Young people with signs and/or symptoms of TBI were included in our study. Severity of TBI was scored using the Glasgow Coma Scale score at presentation in the emergency room (ER) as mild (GCS 13–15), moderate (GCS 9–12) or severe (GCS < 9).[20] The exact time lapse between trauma and admission could not be certified in most cases. The paediatric version of the GCS was used in young preverbal children (2 years or younger).[21] Based on CT or MRI images, we distinguished between abnormalities of the skull (fractures) and abnormalities of the brain (haematoma, contusion, ischemic, diffuse axonal injury (DAI) with or without skull fractures (facial fractures not included)).

2.2. *Data collection*

Information concerning date of the incident, age and gender was derived from the digital or paper patient files. Patients were subdivided into four groups matching preschool (0–3 yrs), primary education (4–11 yrs), secondary education (12–18 yrs) and young adults (19–24 yrs). We also collected data on severity of TBI, circumstances of injury (1. traffic, 2. at home, 3. outdoors, sub activities: a. playing outdoors, b. sports, 4. school/work and 5. 'other causes of injury', sub activities: a. (suspicion of) physical abuse, b. fall under influence of alcohol or drugs intoxication, c. epileptic seizure or syncope). In addition, we derived data on hospital care: imaging type and results (1. no abnormalities, 2. skull fracture, 3. haematoma, 4. brain contusion and combinations of intracerebral injuries), hospitalisation (yes/no, duration), type of care after discharge from the hospital (i.e. 1. outpatient follow-up in paediatrics, (paediatric) neurology, (neuro)surgery, 2. outpatient rehabilitation care, 3. outpatient follow up by other than previously mentioned medical specialists). We also collected data on clinical course, outcome, fatal injuries and long-term physical and/or cognitive complaints after injury (yes/no/unknown). The following complications (i.e. clinical deterioration due to new pathological changes following TBI) were found in the study group: (increase of) haemorrhage, epileptic seizures, deterioration of GCS score, growing skull

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fracture, CNS infection, disorders in plasma sodium levels or intracranial high pressure) (yes/no),

2.3. *Analyses*

We used SPSS statistical software (IBM Company, version 15) to analyse the collected data. We performed multiple frequency analysis to study patient characteristics for severity of brain injury, cause of injury, hospitalisation and follow-up. For proportions, we calculated 95% confidence intervals. For the comparison and analysis of proportions, we used Chi–Square tests. One-way-ANOVA and Kruskal Wallis tests were used for analysis of means and medians respectively. All the performed statistical analyses were 2-tailed tested. One person was included twice in our database because he had an injury to the skull with signs of brain injury on two separate occasions. We excluded the second incident from our data to assure an independent sample for our statistical analysis.

2.4. *Incidence data*

Annual incidence was calculated based on the number of young people aged 0–24 years living in the referral areas of the Erasmus University Hospital, which differ for levels of standard, specialised and intensive care. The Erasmus University Hospital provides standard care for the city of Rotterdam (approximately 163.837 inhabitants 0–24 years). For specialised care the hospital serves the region Rotterdam-Rijnmond (approximately 407.050 inhabitants 0–24 years). Intensive care is provided for the South-West region of the Netherlands (approximately 1.183.747 inhabitants 0–24 years).[22] We extracted the mean number of young people (0–24 yrs) living in these regions in 2007 and 2008 from publications of the Dutch Office of Statistics.[23] In order to calculate annual incidence rates, we divided the number of young people who visited our hospital with TBI in one year by the number of young people living in its different referral areas. In order to calculate the number of patients in our study not living in the Erasmus University Hospital referral area, we checked the ZIP codes for a random sample of 100 TBI patients.

3. Results

3.1. *Patient characteristics*

In 2007 and 2008, 734 young people presented at our hospital with a head trauma of which 472 patients with TBI could be included in our study. Patient characteristics are presented in Table 1. One out of three patients was female. The mean age at TBI was 12.0 years (SD 7.5). The causes of injury differed between age groups ($\chi^2 = 229.19$, df = 12, $p < 0.001$). In children 0–3 years, the cause of injury was most frequently accidents at home. In children 4–11 years, more accidents occurred during sports and playing outdoors. Children 12–18 years were more often involved in traffic accidents. In young adults, accidents were more often caused by other injuries, of which the categories physical abuse (22.4%, 95% CI 14.8–30.0%) and falls associated with alcohol intoxication (10.3%, 95% CI 4.8–19.9%) were prominent (Fig. 1). Based on GCS at presentation at the ER, 342 patients (72.5%: 95% CI 68.4–76.5%) presented with mild TBI. 50 patients (10.6%: 95% CI 7.8–13.4%)

Table 1 – Patient characteristic for the total patient group with traumatic brain injury.

Factor ($n = 472$)	Number	Percent	95% CI
Gender			
Male	317	67.2%	62.9–71.4%
Female	155	32.8%	28.6–37.1%
Age groups			
0–3 yrs	95	20.1%	16.5–23.8%
4–11 yrs	121	25.6%	21.7–29.6%
12–18 yrs	140	29.7%	25.5–34.1%
19–24 yrs	116	24.6%	20.7–28.5%
Cause of injury			
1. Traffic	192	40.7%	36.2–45.1%
2. At home	89	18.9%	15.3–22.4%
3. Sports	35	7.4%	5.1–9.8%
4. School/work/day-care	21	4.4%	2.6–6.3%
5. Playing outdoors	33	7.0%	4.7–9.3%
6. (suspicious of) physical abuse	46	9.7%	7.1–12.4%
7. fall under influence of alcohol or intoxication otherwise	18	3.8%	2.1–5.5%
8. epileptic seizure of syncope or collaps e.c.i.	9	1.9%	0.7–3.1%
9. event unknown	29	6.1%	4.0–8.3%
Additional imaging	398	84.3%	81.0–87.6%
Normal results	228	57.3%	52.4–62.1%
Abnormal results	170	42.7%	37.9–47.6%
Hospitalisation	343	72.7%	68.6–76.7%
Post-care	240	50.8%	46.3–55.4%
Complications	47	10.0%	7.3–12.8%
Fatal Injury	24	5.1%	3.1–7.1%

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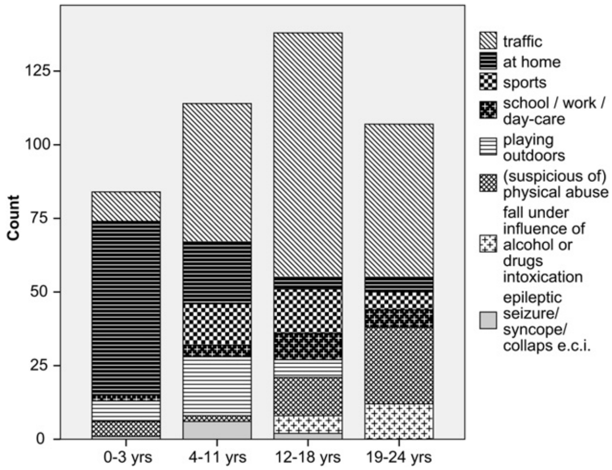

Fig. 1 – Stacked bar chart representing causes of injury per age group in 472 young people with traumatic brain injury.

had a moderate TBI and 80 patients (16.9%: 95% CI 13.6–20.3%) were classified as severe TBI. The mean ages of the children with mild (mean 11.7years, SD 7.5) and moderate (mean 10.6 years, SD 7.7) brain injury did not differ but patients with severe brain injury (mean 13.9 years, SD 6.9) were older ($F = 3.96$, df $= 2$, $p = 0.020$). Sixteen patients in the severe TBI group (20%) recovered remarkably fast. These children (mean age 10.9 years, SD 6.1) were all initially admitted to the Intensive Care Unit and in need of artificial respiratory support and subsequently completely recovered neurologically within several hours.

3.2. Incidence data

The annual incidence of mild TBI calculated from the 2007–2008 cohort was estimated at 104.4 patients per 100.000 young people 1 month - 24 yrs old in the city Rotterdam. The annual incidence of moderate TBI in this two-year period was estimated at 6.1 per 100.000 young people in the Rotterdam-Rijnmond area. The annual incidence of severe TBI was estimated at 3.4 per 100.000 young people in the South-West region of the Netherlands. The total annual incidence of TBI in the catchment area of the Erasmus University Hospital was calculated at 113.9 per 100.000 young people. The annual incidence of admission to the hospital was 74.5 per 100.000 young people and the estimated annual incidence of fatal TBI was 1.5 per 100.000 young people. In order to compare our data with those from the literature in the group of children under 15 years of age the annual incidence of TBI in children aged 1 month- 15 years from this cohort are represented in Table 2.[1,3–5,7–11]

3.3. Clinical details

Evaluation and management of the patients with TBI in our hospital is carried out according to the guidelines of the Dutch Society of Neurology.[24] In Table 3 clinical parameters of the identified TBI patients are presented. In 398 patients (84.3%) a brain CT scan (394 patients) or MRI scan was performed. In the group classified as severe TBI, one child died before a CT scan could be performed. In one child in the severe TBI group and one child in the moderate TBI group, GCS normalised so fast after admission to the ER that sedation would have been

Table 2 – Summary of data from studies on the incidence of TBI in children and young adults.

Study (ref)	Inclusion criteria	Annual incidence of TBI
Present study	TBI patients aged 0–15 years	130.3 per 100.000 children 0–14 years 111.6 mild TBI per 100.000 children 0–14 years 5.9 moderate TBI 100.000 children 0–14 years 2.8 severe TBI 100.000 children 0–14 years 1.3 deaths per 100.000 children 0–14 years
Langois et al., 2004 and 2005, USA[1,5]	ICD-codes for TBI and minor head injury: children aged 0–14 years	798.8 per 100.000 children 0–14 years 4.5 deaths per 100.000 children 0–14 years 63.0 hospitalisations per 100.000 children 0–14 years
Meerhof et al., 1997, the Netherlands[3]	TBI and minor head injury in total population	242.7 per 100.000 children 0–14 years
Kraus et al., 1990, USA[4]	Hospitalised TBI patients aged 0–14 years and 0–19 years	230 hospitalisations per 100.000 children 0–14 years 219.4 hospitalisations per 100.000 children 0–19 years 10.0 deaths per 100.000 children 0–19 years
Hawley et al., 2003, United Kingdom[7]	>24 h hospitalised TBI patients aged 0–14 years	280 per 100.000 children aged 0–14 years
Ventsel et al., 2007, Estonia[8]	TBI patients aged 0–14 years	369 per 100.000 children 0–14 years 3.1 deaths per 100.000 children 0–14 years
Reid et al., 2001, USA[9]	TBI deaths and hospitalisations in patients aged 0–19 years	73.5 per 100.000 children 0–19 years 9.3 deaths per 100.000 children 0–19 years
Schneier et al., 2006, USA[10]	Hospitalised TBI patients aged 0–16 years	70 per 100.000 children 0–16 years
Emanuelson et al., 1997, Sweden[11]	TBI patients aged 0–17 years with TBI including one of the following criteria: >1 h loss of consciousness; clinical, neurophysiological or neuroradiological evidence of brain contusion	12 per 100.000 children 0–17 years

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Table 3 – Clinical parameters of the patients with Traumatic Brain Injury ($n = 472$).

	Mild TBI ($n = 342$)		Moderate TBI ($n = 50$)		Severe TBI ($n = 80$)	
Mean age (years, months) (SD)	11.7(7.5)		10.6 (7.7)		13.9 (6.9)	
Imaging performed (*n*)[a]	271	79.2%	49	98,0%	78	97.5%
Hospitalisation (*n*)[a]	213	62.3%	50	100%	80	100%
Median days (IQR))	1 (1–3)		3 (1–7)		7 (2–19)	
Out patient care (*n*) [b]	**143**	**42.1%**	**41**	**82%**	**56**	**96.6%**
Outpatient clinic (neurology, neurosurgery, paediatrics)	*97*	*68.3%*	*23*	*56.1%*	*17*	*30.4%*
Rehabilitation therapy	*13*	*9.2%*	*16*	*39 %*	*36*	*64.3%*
Other medical specialist	*32*	*22.5%*	*2*	*4.9%*	*3*	*5.4%*
Complication (*n*)[a]	9	2.6%	9	18%	29	36.3%
Fatal injury (*n*)	2		–		22	
Reported Long-term cognitive symptoms (*n*) [b]						
Yes	24	*16.8%*	18	*43.9%*	35	*62.5%*
No	39	*27.3%*	10	*24.4%*	7	*12.5%*
Unknown	80	*55.9%*	13	*41.7%*	14	*25%*

Legend: n = number of patients, SD = standard deviation. IQR = inter quartile range.
Figures for out patient care and reported long-term cognitive symptoms are corrected for fatal injuries and these figures only include survivors.
Percentages for long-term symptoms are calculated as a percentage of the patients who received post-care in the categories of mild, moderate and severe traumatic brain injury.
a percentage calculated as a proportion of the subgroups respectively mild, moderate and severe TBI.
b percentages calculated as a proportion of the patients who received out patient care after discharge from the hospital (bold figures) in the subgroups with mild, moderate and severe TBI.

needed to make a brain CT scan. For this reason they were admitted to the neurological ward for intensive 24 h observation without radiological evaluation. In the mild TBI group, 271 children (79.2%) had a brain CT scan following the guidelines for patients with mild TBI of the Dutch Society of Neurology.[24] Traumatic abnormalities at neuroimaging were found in 72 (26.6%) of these children (Fig. 2). The ratio for abnormalities at neuroimaging was 4.3 out of 10 images. In comparison to the patients with mild TBI, patients classified as having moderate or severe TBI more frequently showed abnormalities on neuroimaging ($\chi^2 = 95.06$, df = 2, $p < 0.001$) (Table 4). Of all included patients, 343 (72.7%) were admitted to the hospital. The 129 children that were not admitted were all classified as mild TBI patients. 78 of them (60%) had a normal brain CT scan which contributed to the decision to sent them home Patients with severe brain injury were hospitalised for a median 7 days (IQR 2–9) versus 3 days (IQR 1–7) for moderate and 1 day (IQR 1–3) for mild TBI ($\chi^2 = 53.78$, df = 2, $p < 0.001$) (Table 4). Patients with TBI caused by traffic accidents were significantly more often admitted to the hospital in comparison to the other patients ($\chi^2 = 23.03$, df = 4, $p < 0.001$) (Table 4): 83.9% of them were hospitalised versus 74.2% of the patients with accidents at home, 63.2% by accidents outside, 71.4% by accidents at school/work and 58.3% by 'other causes of injury'. After discharge, patients with severe TBI were significantly more frequent enrolled in outpatient facilities compared to patients with mild or moderate TBI ($\chi^2 = 41.99$, df = 2, $p < 0.001$) (Table 4). The type of outpatient care for mild, moderate and severe brain injured patients differed. Outpatient care for patients with mild TBI was limited to outpatient visits or visits to other medical specialists (Table 3). Patients with severe TBI enrolled rehabilitation treatment programs significantly more frequent than patients with mild or moderate TBI ($\chi^2 = 68.78$, df = 4, $p < 0.001$) (Table 4). In patients with severe TBI a significantly larger number of complications occurred during the clinical course (Table 3) ($\chi^2 = 85{,}50$, df = 2, $p < 0.001$). In Fig. 3, patient counts for type of complications in young people with mild, moderate en severe TBI are presented. Twenty-four patients (5.1%: 95% CI3.1–7.1%) died of which 22 patients had severe TBI (14 patients with polytrauma). The two other patients were initially classified as having mild TBI based on their GCS score at presentation. One was a haemophilia patient who died due to progressive intracerebral haematoma, despite maximal treatment with factor VIII. The other patient died of diffuse delayed cerebral oedema, after a relatively mild trauma. Nineteen deadly injuries (79.2%) were caused by traffic accidents. Patients with severe TBI had significantly more persisting long-term physical and cognitive symptoms in comparison to moderate or mild TBI patients ($\chi^2 = 21.75$, df = 2, $p < 0.001$) (Table 4). The mean age of patients who reported long-term cognitive sequelae was significantly higher (13.2 years, SD 6.7) than of patients who did not (8.9 years, SD 6.9) ($F = 5.93$, df = 2, $p = 0.003$).

4. Discussion

We performed an extensive search strategy for patients with a newly acquired TBI in our hospital. A search strategy by ICD-codes alone may be incomplete.[25] The data collection in this study is more accurate because additional cases were identified by the search terms in the patient reports and supplemental data bases. We estimated the mean total incidence of TBI in the catchment area of the Erasmus University Hospital in 2007–2008 as 113.9 cases per 100.000 children and young adults. In a previous Dutch study the incidence of traumatic skull and brain injury was estimated 836 people per 100.000, of which were 242.7 children aged <15 years per 100.000 persons.[3] In the USA, the incidence of TBI is estimated 798.8 children 0–14 years per 100.000 annually between 1995 and 2001.[1,5] A comparison of annual incidences found in other studies is difficult, because in many of them minor head

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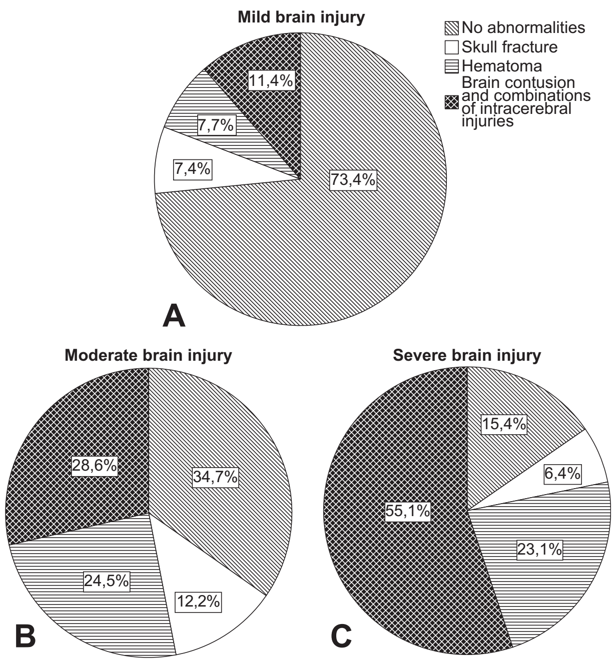

Fig. 2 – Pie charts representing results of cerebral CT or MRI imaging in 398 patients with traumatic brain injury: A: mild traumatic brain injury, B: moderate traumatic brain injury: C. severe traumatic brain injury.

injuries without brain involvement were included and because different search strategies were used.[3–11] Our estimated hospitalisation rate of 74.5 cases per 100.000 children and young adults aged 0–24 years agrees with estimated incidence for TBI hospitalisation in two earlier studies.[9,10]

The Erasmus University Hospital is a tertiary care center and young people with moderate or severe TBI from the defined regions are all referred to our hospital. Because the data were calculated with different denominators, the estimations of incidence of severe and moderate TBI are not clouded by the academic ratio of severity of TBI. The estimated incidence of mild TBI is however a minimum incidence for Rotterdam, because we do not exactly know how many children present with mild TBI at the emergency rooms of the three smaller hospitals in Rotterdam, or how many patients did not present at a hospital at all. Rotterdam is a large city that appeals to students and tourists for study, work and leisure time. In agreement with findings in the previous Dutch study in which at random sample 21% of the patients did not live in the hospital's referral area we found that 29% (27% mild TBI, 2% moderate TBI) of the patients did not live (at the moment of data collection) in the referral areas of our hospital.[3] This finding would mean that our estimated annual incidences are too high. However, the latter finding may well be balanced by the number of children with TBI who presented at one of the smaller hospitals in Rotterdam or were admitted to hospitals elsewhere while visiting other cities. Although if we exclude the patients who did not live in the hospitals referral area, we can calculate the minimum annual incidence for mild TBI at 74.2 per 100.000 young people. The minimum incidence for moderate TBI is calculated at 6.0 per 100.000 young people. At random sample only 2% of the patients with moderate TBI and none with severe TBI did not live in the hospitals catchments area.

A difference in causes of injury for the age groups is expected, because the children in the different age groups also have different activities of interest. As expected traffic is the most common cause of severe TBI and fatal injuries.[26,27] The finding that in patients with severe TBI mean age is significantly higher is explained by the more risky behaviour of young adolescents who more often participate in traffic, drink alcohol and are involved in brawls. The latter two age related factors are also responsible for the high rate of adolescents and young adults with (suspicion of) abusive head trauma. The GCS as measure of the severity of the TBI is an important tool to predict outcome. However, in some patients use of alcohol may have influenced the classification of severity of the trauma.[20] For example one of the included patients was hospitalised on an ICU with a GCS <9 and alcohol intoxication and perhaps should have been included in the mild TBI group. On the other hand 16 patients with an initial low GCS score recovered remarkably fast confirming that GCS score does not always accurately predict the outcome of severe TBI in children.[28,29]

CNS imaging was performed in 398 of the TBI patients (84,3%). In the Octopus study was demonstrated that in children older than 6 years with mild TBI, clinical observation was equally safe as discharge from the hospital after a normal brain CT. In contrast what might be expected, the large number of CT

Table 4 – Chi-squared contingency table with parameters that reached statistical significance when compared with Chi-squared test.

Cause of injury	Age group	$\chi^2 = 229.19$, df = 12, $p < 0.001$
Accidents at home	0–3 years	
Sports and playing outdoors	4–11 years	
Traffic accidents	12–18 years	
Other causes	19–24 years	
Neuroimaging more frequently abnormal	Moderate and severe TBI vs mild TBI	$\chi^2 = 95.06$, df = 2, $p < 0.001$
More frequently admitted to the hospital	Victims of traffic accidents vs all other causes of TBI	$\chi^2 = 23.03$, df = 4, $p < 0.001$
More frequently enroled in outpatient facilities	Severe TBI vs mild and moderate TBI	$\chi^2 = 41.99$, df = 2, $p < 0.001$
Higher number of complications	Severe TBI vs mild and moderate TBI	$\chi^2 = 85{,}50$, df = 2, $p < 0.001$
Longer duration of hospitalisation	Severe TBI vs mild and moderate TBI	$\chi^2 = 53.78$, df = 2, $p < 0.001$
More persisting long-term physical and cognitive problems	Severe TBI vs mild and moderate TBI	$\chi^2 = 21.75$, df = 2, $p < 0.001$

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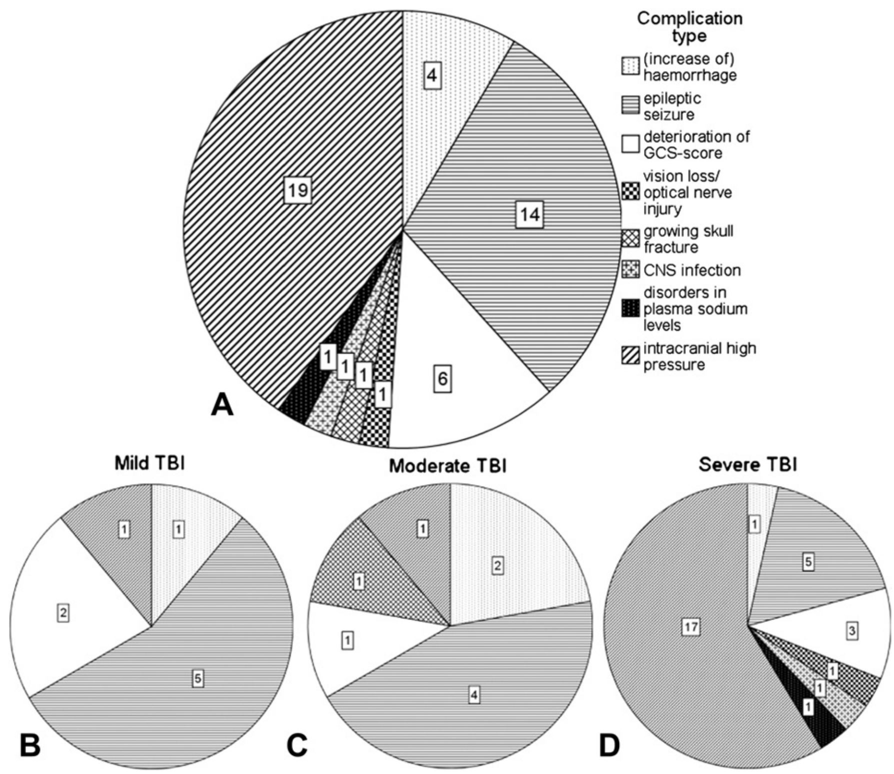

Fig. 3 – Pie charts with patient counts fort type of complications: A total TBI group (n = 47), B mild TBI (=9), C moderate TBI (n = 9), D severe TBI (n = 29).

scans in children with mild TBI (60%) did not reduce admission to the hospital. Of the children with normal findings on brain CT scan only 39% was sent home after evaluation versus 72% of the children that did not have a CT scan at all. This was explained by the fact that 50% of the children with mild TBI who had a CT scan were either younger than 6 years, had other traumatic abnormalities that necessitated admission or did not have a competent carer at home.[30]

In the present study 24 children died. The incidence for fatal TBI was estimated 1.5 cases per 100.000 children and young adults in 2007 en 2008. The fatal outcome of TBI is almost for certain an underestimation because approximately the same number never reaches a hospital and dies at the scene of the incident.[26,27] Fourteen of the 22 patients with severe TBI who died were polytrauma patients (63.6%). In these patients extra-cranial causes may have contributed to the fatal course. Two patients in this study who died of a fatal brain injury were initially classified as mild TBI. One patient had as evident risk factor haemophilia.[31] The other patient, a three year old girl died due to delayed cerebral oedema after a trivial head trauma. This particular clinical course has been described in patients with a mutation in the calcium channels with sporadic hemiplegic migraine.[32,33] Regretfully, this was not assessed in this particular patient. Our observations supports recent findings that in patients with mild and moderately severe traumatic brain injury the GCS has a limited value to predict survival or death.[34,35]

Data on long-term sequelae were not complete because not all patients with TBI received care after discharge from the hospital. Some patients had follow-up by other medical specialists than neurologists or neurosurgeons or in other hospitals and rehabilitation centres. In the patients who did report on presence or absence of long-term symptoms, mean age was higher than of the patients that did not. This may be explained by the older children being more capable to express long-term sequelae than younger children. 16.8% of the mild TBI patients who had follow up (n = 143) reported long-term cognitive sequelae. An important finding is that 42.0% of these young people had no abnormalities on brain CT scan at admission. Our findings are in agreement with those of a British postal questionnaire survey in which approximately 20% of children with mild TBI suffered from sequelae such as poor concentration, personality change and educational problems after TBI.[36] Recently it has become clear that for the group of children and young adults with mild TBI the need for diagnosis and rehabilitation treatment of acquired brain injury sequelae is underestimated. Cognitive rehabilitation programs are rarely offered to children with mild or moderate TBI(12). Extrapolating our data to the Dutch population would mean that each year approximately 470 children with mild or moderate TBI would benefit from such a program, apart from the children who would be identified as needing more intensive rehabilitation programs.[12,17]

5. Conclusions

We estimated that in the catchment area of the Erasmus University Hospital the mean total incidence of TBI in 2007–2008, in children and young people 1month- 24 years of

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age was 113.9 cases per 100.000; mild TBI 104.4 cases per 100.000, moderate TBI 6.1 cases per 100.000 and severe TBI 3.4 cases per 100.000 young people. In the mild TBI group almost 17% of the patients reported sequelae. The finding that 42% of them had a normal brain CT scan at admission underwrites the necessity of careful follow up of children and young people with mild TBI.

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