Posttraumatic epilepsy: long-term follow-up of children with mild traumatic brain injury

Amit Keret, MD,¹ Odeya Bennett-Back, MD,³ Guy Rosenthal, MD,² Tal Gilboa, MD,³ Moatasim Shweiki, MD,^{1,2} Yigal Shoshan, MD,² and Mony Benifla, MD^{1,2}

¹Pediatric Neurosurgery Unit, ²Neurosurgery Department, and ³Pediatric Neurology Department, Hadassah Ein Kerem Medical Center, Jerusalem, Israel

OBJECTIVE Posttraumatic epilepsy (PTE) is a known complication of traumatic brain injury (TBI). The true incidence of PTE in children is still uncertain, because most research has been based primarily on adults. This study aimed to determine the true incidence of PTE in a pediatric population with mild TBI (MTBI) and to identify risk factors for the development of epileptic events.

METHODS Data were collected from electronic medical records of children 0–17 years of age, who were admitted to a single medical center between 2007 and 2009 with a diagnosis of MTBI. This prospective research consisted of a telephone survey between 2015 and 2016 of children or their caregivers, querying for information about epileptic episodes and current seizure and neurological status. The primary outcome measure was the incidence of epilepsy following TBI, which was defined as ≥ 2 unprovoked seizure episodes. Posttraumatic seizure (PTS) was defined as a single, nonrecurrent convulsive episode that occurred > 24 hours following injury. Seizures within 24 hours of the injury were defined as immediate PTS.

RESULTS Of 290 children eligible for this study, 191 of them or their caregivers were reached by telephone survey and were included in the analysis. Most injuries (80.6%) were due to falls. Six children had immediate PTS. All children underwent CT imaging; of them, 72.8% demonstrated fractures and 10.5% did not demonstrate acute findings. The mean follow-up was 7.4 years. Seven children (3.7%) experienced PTS; of them, 6 (85.7%) developed epilepsy and 3 (42.9%) developed intractable epilepsy. The overall incidence of epilepsy and intractable epilepsy in this cohort was 3.1% and 1.6%, respectively. None of the children who had immediate PTS developed epilepsy. Children who developed epilepsy spent an average of 2 extra days in the hospital at the time of the injury. The mean time between trauma and onset of seizures was 3.1 years. Immediate PTS was not correlated with PTE.

CONCLUSIONS In this analysis of data from medical records and long-term follow-up, MTBI was found to confer increased risk for the development of PTE and intractable PTE, of 4.5 and 8 times higher, respectively. As has been established in adults, these findings confirm that MTBI increases the risk for PTE in the pediatric population.

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KEY WORDS posttraumatic epilepsy; mild traumatic brain injury; pediatric neurosurgery; trauma

IN the US alone, more than 470,000 children 0–14 years of age visit the emergency department (ED) for traumatic brain injury (TBI) each year.¹⁵ Approximately 70%–90% of children admitted for head trauma are classified as having mild TBI (MTBI)^{10,34} and generally require short hospital stays for monitoring and conservative care.^{15,21} Nevertheless, a wide spectrum of long-term neurological, psychological, and psychosocial morbidities can be attributed to MTBI.^{9,29}

Epilepsy is a known complication of TBI in all age groups.^{17,39} An estimated 5%–21% of children of all ages experience posttraumatic seizures (PTSs). In 32%–40% of them, the seizures recur,^{33,39,41} an incidence rate significantly higher than the incidence rate of epilepsy in the general population, which is estimated at 0.7%.²⁰ Several risk factors have been attributed to the development of posttraumatic epilepsy (PTE). Some factors, such as injury severity^{4,5,12,16,18,33,39} and younger age,^{7,7,17,36} have been con-

ABBREVIATIONS AED = antiepileptic drug; ED = emergency department; EEG = electroencephalography; GCS = Glasgow Coma Scale; GCSOA = GCS score on arrival; LOH = length of hospitalization; MTBI = mild TBI; MVA = motor vehicle accident; PTE = posttraumatic epilepsy; PTS = posttraumatic seizure; TBI = traumatic brain injury. **SUBMITTED** October 15, 2016. **ACCEPTED** February 20, 2017.

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sistently identified, whereas others, such as intracranial hemorrhage^{17,18,30} and seizure episodes in the hours following TBI,^{4,7,12,16,20,41} are controversial. Furthermore, a correlation between these risk factors and PTE has not been confirmed, either in MTBI or in the pediatric population.⁵

The use of antiepileptic drugs (AEDs) is common in the management of epileptic disorders; however, the indication for prophylactic use in the setting of TBI is unclear.^{1,5} Information regarding the usefulness of AED prophylaxis in the setting of MTBI is scarce; these drugs are not free of adverse effects.^{1,17} Therefore, additional evidence is needed to provide clinicians with tools to assess risk of PTE in children and upon which to base clinical decisions.^{6,39,41}

In this study with long-term follow-up, we aimed to determine the incidence of PTE in children with MTBI, as well as to investigate characteristics relating to presentation, management, and overall hospitalization, to identify independent risk factors that might predict the development of epileptic events.

Methods

Study Population and Case Selection

After obtaining IRB approval from Hadassah Medical Organization, our institution's electronic medical record database (Mahar, proprietary software) was queried for children younger than 18 years hospitalized between January 2007 and December 2009 with a diagnosis of TBI. Children were excluded from the study if presentation to the ED occurred > 24 hours after the insult or if the child had prior diagnoses of epilepsy. An additional exclusion criterion was the diagnosis, at any time during follow-up, of an epileptogenic brain lesion or a chronic illness that could cause epileptic episodes.

Retrospective Data Retrieval

Demographic data, as well as details of injury mechanism and posttraumatic clinical features, were collected. The mechanism of injury was categorized as fall from height ≤ 1 m, fall from height > 1 m, motor vehicle accident (MVA), and blunt trauma.

Case records were investigated for clinical and neurological assessment at arrival, as well as the assessment of injury severity, as defined by the Glasgow Coma Scale Score on Arrival (GCSSOA). Mild brain injury was defined as GCSSOA ≥ 14 .³⁵ Only children with injuries of mild severity were included in the study.

Information was collected from CT studies performed upon initial presentation. Each descriptive report was coded into the following categories: appearance of fracture, hematoma, or contusion and their locations; and presence of pneumocephalus, mass effect, or edema. The presence or absence of a mass effect was determined by the evidence of either a midline shift of the falx cerebri or effacement of any cerebral ventricle. Original imaging data were reviewed in a minority of cases in which no findings were documented in the medical records. Inpatient admission records were queried regarding the need for primary neurological and/or other surgery, length of hospitalization (LOH), and the presence of neurological deficits at the time of discharge.

Prospective Data Collection

Between December 2015 and July 2016, all children included in the study were sought for a telephone survey by the study researchers. In cases in which children were < 18 years at the time of follow-up, caregivers were surveyed. Permission was obtained from the ethical committee of Hadassah Medical Center, and verbal informed consent was received at the beginning of every contact.

The primary outcome measure was the incidence of epilepsy following TBI, which was defined as ≥ 2 unprovoked seizure episodes.^{12,17} Conversely, PTS was defined as a single, nonrecurrent convulsive episode that occurred > 24 hours after injury.^{1,42} Immediate PTS refers to seizures occurring within the first 24 hours after injury.²² Using a standardized questionnaire, patients or caregivers were surveyed regarding any epileptic episodes that occurred after discharge, past and current use of AEDs, and current epileptic status. Finally, questions were asked regarding current cognitive, mental, and intellectual status, and the presence of disabilities requiring ongoing care.

Statistical Analysis

Information was aggregated into a custom data sheet (Microsoft Office Excel, Microsoft Corporation). The study design and analysis were supervised by a professional statistician. Statistical analysis was performed using IBM SPSS Statistics (IBM Corporation). Descriptive statistics were calculated for all categorical variables; means, SDs, medians, and ranges were calculated for numeric variables. To examine associations of categorical and quantitative prognostic factors with the development of PTE, the Fisher exact test and Mann-Whitney U-test were applied, respectively. Correlation between prognostic factors and the time to occurrence of the first PTS was assessed by Kaplan-Meier analysis. Statistical analyses were 2-tailed and significance was set to a p value ≤ 0.05 .

Results

Patient Population

From a total of 374 cases of TBI that were eligible for the study according to inclusion and exclusion criteria, 290 children suffered from MTBI. Of these, 96 children were excluded from the analysis due to lack of follow-up by telephone survey, and 3 caregivers declined to participate in the study. A total of 191 patients (65.9%) were included in the final data analysis.

Complete demographic data, injury details, and hospitalization characteristics are given in Table 1. There were no statistically significant differences in any of the attributes assessed between children in the final cohort and children lost to follow-up (Table 2). The mean age at admission was 4 ± 3.5 years (median 3 years, range 24 days to 16.6 years), and more than half of patients were boys (122 boys, 63.9%). Regarding time to admission, 150 children (78.5%) presented to the ED ≤ 6 hours after the injury. A fall from height was the most common cause of injury (80 children [41.9%] fell from a height ≤ 1 m, and 74 [38.7%] fell from a height > 1 m); 18 injuries (9.4%) were caused by an MVA. Six children (3.1%) had immediate

TABLE 1. Demographic data, injury details, and hospitalization characteristics of 191 patients

Characteristic	All Patients	Risk Factor Analysis		
		Patients w/o PTE	Patients w/ PTE	p Value
No. of patients	191	185	6	
Age in yrs, mean $\pm$ SD	4.0 $\pm$ 3.49	4.0 $\pm$ 3.44	5.4 $\pm$ 4.90	0.46
Age in yrs, no. (%)				0.72
<1	48	46 (95.8)	2 (4.2)	
1–4	74	73 (98.6)	1 (1.4)	
5–14	68	65 (95.6)	3 (4.4)	
>14	1	1 (100)	0 (0)	
Sex, no. (%)				0.42
F	69 (36.1)	68 (98.6)	1 (1.4)	
M	122 (63.9)	117 (95.9)	5 (4.1)	
Time from injury, no. (%)				0.61
≤ 6 hrs	150 (78.5)	146 (97.3)	4 (2.7)	
>6 hrs	41 (21.5)	39 (95.1)	2 (4.9)	
Mechanism of injury, no. (%)				0.78
Fall ≤ 1 m	80 (41.9)	77 (96.3)	3 (3.8)	
Fall >1 m	74 (38.7)	72 (97.3)	2 (2.7)	
MVA	18 (9.4)	17 (94.4)	1 (5.6)	
Blunt object	19 (9.9)	19 (100)	0 (0)	
Immediate seizure, no. (%)	6 (3.1)	6 (100)	0 (0)	NS
Amnesia, no. (%)	11 (5.8)	11 (100)	0 (0)	NS
CT result, no. (%)				
Fracture	139 (72.8)	135 (97.1)	4 (2.9)	0.66
Fracture only	78 (40.8)	77 (98.7)	1 (1.3)	0.40
Intracranial hemorrhage	58 (30.4)	56 (96.6)	2 (3.4)	NS
Contusion	29 (15.2)	28 (96.6)	1 (3.4)	NS
Mass effect	3 (1.6)	3 (100)	0 (0)	NS
Edema	1 (0.5)	1 (100)	0 (0)	NS
No abnormal findings	20 (10.5)	18 (90)	2 (10)	0.12
Require neurological surgery, no. (%)	9 (4.7)	9 (100)	0 (0)	NS
LOH in days, mean $\pm$ SD	3.1 $\pm$ 1.86	3.1 $\pm$ 1.80	4.9 $\pm$ 2.86	0.038
Impairment on discharge, no. (%)	3 (1.6)	3 (100)	0 (0)	NS

NS = nonsignificant.

PTS for which a prophylactic AED (either valproic acid or phenytoin) was prescribed for 1 week. Eleven children (5.8%) had some degree of anterograde amnesia. Nine children (4.7%) suffered injuries that required neurological surgery due to epidural hematoma or depressed skull fracture. The mean LOH was 3.1 ± 1.86 days (median 3 days, range 0–16 days). Three children (1.6%) were discharged with neurological impairment. One had a left parietal fracture and subarachnoid hemorrhage and was discharged with a left gaze. A second patient required craniotomy and elevation of a right parietal depressed fracture and was discharged with right cranial nerve VI palsy.

TABLE 2. Comparison of characteristics between children included in the final cohort and children lost to follow-up

Characteristic	Final Cohort (n = 191)	Lost to FU or Refused (n = 99)	p Value
Age in yrs, mean $\pm$ SD	4.0 $\pm$ 3.49	3.8 $\pm$ 3.46	0.62
Female sex, no. (%)	69 (36.1)	41 (41.4)	0.44
Time from injury >6 hrs, no. (%)	41 (21.5)	15 (15.2)	0.21
Mechanism of injury, no. (%)			0.65
Fall ≤ 1 m	80 (41.9)	48 (48.5)	
Fall >1 m	74 (38.7)	33 (33.3)	
MVA	18 (9.4)	7 (7.1)	
Blunt object	19 (9.9)	11 (11.1)	
Immediate seizure, no. (%)	6 (3.1)	4 (4.0)	0.74
Amnesia, no. (%)	11 (5.8)	2 (2.0)	0.23
CT result, no. (%)			0.35
Fracture only	78 (40.8)	42 (42.4)	
Fracture & other features	61 (31.9)	39 (39.4)	
No abnormal findings	20 (10.5)	7 (7.1)	
Require neurological surgery, no. (%)	9 (4.7)	7 (7.1)	0.42
LOH in days, mean $\pm$ SD	3.1 $\pm$ 1.86	2.9 $\pm$ 1.66	0.24
Impairment on discharge, no. (%)	3 (1.6)	2 (2.0)	1.00

FU = follow-up.

A third patient, who experienced immediate seizures and suffered a right parietal minimally depressed fracture, was discharged with left arm paresis.

CT Imaging Features

Upon review of CT scans at admission, 139 children (72.8%) were found to have ≥ 1 skull fractures. Evidence of intracranial hemorrhage was present in 58 children (30.4%), and 29 (15.2%) had some form of brain contusion. Twenty children (10.5%) had CT scans that were interpreted as having no acute findings.

Incidence of Epilepsy

The mean length of follow-up was 7.4 years (range 6.0–8.9 years). Of 191 children, 7 (3.7%) experienced PTS; of them, 6 (85.7%) developed PTE. Tables 3 and 4 summarize the characteristics of children who developed PTS and PTE.

The mean age at admission of patients with PTE was 5 years. Two children (33.3%) were injured due to falls from a height > 1 m. CT scans of 4 of the patients (66.7%) who developed PTE demonstrated signs of a linear skull fracture; for 2 patients (33.3%), CT scans were interpreted as normal. The mean LOH for children who subsequently had epileptic episodes was 5 days (range 2.1–10.0 days), and none had evidence of neurological deficits at the time of discharge. The mean time between trauma and onset of seizures was 3 years (median 3.2 years, range 7 days to 7.1 years). Of the 6 children who developed PTE, 4 (66.7%) are currently treated with AEDs. Three children (50.0%) experience intractable seizures despite pharmacological

TABLE 3. Current status of 7 children who suffered from PTS

Characteristic	Value
Time to seizure in yrs, mean $\pm$ SD	3.2 $\pm$ 2.47
Active PTE, no. (%)	6 (85.7)
Current use of AED, no. (%)	4 (57.1)
Intractable epilepsy, no. (%)	3 (42.9)
GOS score at FU, mean $\pm$ SD	4.7 $\pm$ 0.49

GOS = Glasgow Outcome Scale.

treatment (1.6% of the total cohort). Two children have mild-to-moderate developmental retardation.

None of the children who experienced an immediate seizure, who were prescribed prophylactic AEDs, or who required neurological surgery developed PTE. Five of 6 children with epilepsy underwent an electroencephalography (EEG) examination; 3 showed normal electrical activity, whereas 2 demonstrated focal epileptiform discharges.

Risk Factor Analysis

Table 1 presents an analysis of associations between possible prognostic factors and the onset of PTSs. Neither the demographic characteristics that were investigated nor the clinical features upon presentation showed significant association with the onset of seizures. Children with normal CT scans had a 10% risk (2 of 20 children) to develop

PTE, compared with 2.3% in children with abnormal CT scans (that is, skull fracture or intracranial hemorrhage); however, this difference was not statistically significant ($p = 0.12$). LOH was the only factor to show a statistically significant association with the development of PTE, with a mean of 4.9 days (range 2–10 days) for children who developed PTE compared with 3.1 days (range 0–16 days) for those who did not ($p = 0.038$).

Discussion

Incidence of Epilepsy

We report a 3.1% rate of PTE in children admitted for MTBI, which is almost 4.5 times higher than the rate of epilepsy in the general population. Few studies have focused on MTBI in the pediatric population. In a retrospective Indian study³⁶ comprising 400 children < 12 years of age with TBI of all severities, MTBI resulted in a 15.6% incidence of PTS. Of 1017 cases of PTE analyzed from a national Danish register of > 1.6 million people,¹² MTBI was found to confer a 2-fold increased risk of developing epilepsy in 885 individuals who were $\leq$ 15 years old, even > 10 years after injury. On subgroup analysis, younger age (0–15 years) conferred a relative risk of 2.06–2.25. Comparison of these findings with other reports is difficult because the definition of MTBI used was based on that given by the American Congress of Rehabilitation Medicine²⁵ rather than strictly by the GCSOA.

In contrast to the above, an overall 1.9% incidence of

TABLE 4. Details of first epileptic episode, current epilepsy status, and ongoing AED treatment in 6 children who developed PTE

Variable	Patient No. (sex)					
	1 (M)	2 (M)	3 (M)	4 (M)	5 (F)	6 (M)
Age at time of TBI*	7.5 yrs	11 yrs	7 mos	1.5 yrs	10 mos	10.5 yrs
TBI characteristic						
Mechanism	Fall >1 m	MVA	Fall $\leq$ 1 m	Fall >1 m	Fall $\leq$ 1 m	Fall <1 m
LOC	—	+	—	—	—	+
Emesis	—	1	—	—	Multiple	3
Apathy/lethargy	—	+	—	—	+	+
CT study feature						
Skull fracture	Linear	Linear	Linear	—	Linear	—
Intracranial hematoma	Epidural	—	—	—	Epidural	—
LOH in days	3	10	6	2	5	3
Impairment on discharge	—	—	—	—	—	—
Time btwn TBI & first PTS*	2 yrs	4 yrs	4.5 yrs	6 mos	7 yrs	1 wk
Epilepsy status						
Frequency of episodes	1–2/mo	Many	1/mo	1/mo	Seldom	Seldom
Seizure type	GTC	Absence	GTC	PS	PC	NA
No. of AED agents	5	—	2	1	1	—
Intractable epilepsy	+	+	+	—	—	—
EEG findings	Normal	NA	Normal	Normal	Epileptiform	Epileptiform
GOS score at FU	4	5	4	5	5	5

EEG = electroencephalography; GTC = generalized tonic-clonic; LOC = loss of consciousness; NA = not available; PC = complex partial; PS = simple partial.

* Rounded for readability.

PTS was recently reported in a study of 5148 children with MTBI.²¹ Although the investigators concluded that this is a low incidence rate, it is in fact higher than that of the general population (0.7%). Furthermore, seizure recurrence was not directly confirmed; rather, it was deduced based on data regarding AED and EEG studies. More importantly, long-term follow-up was sought for only 38 children who underwent EEG evaluation (0.7%), a subset of patients that was admittedly unrepresentative of the study population. In our report, follow-up was achieved for nearly 66% of patients and involved direct verification of convulsive status. We believe that this methodology supports our reported 3.1% PTE incidence as being more valid to the population in question.

Immediate Seizures

We did not find any association between immediate PTS and PTE; there was no overlap of patients between these groups. Immediate PTS refers to seizures that occur within the first 24 hours after injury.²² It has been postulated that immediate and late PTS differ in their underlying pathophysiology.¹ Whereas immediate seizures stem from ischemia and neuronal hypoxia, late PTS is associated with gradual synaptic and axonal transformations that result in higher excitatory states,² which in turn dispose toward PTE. This etiology was supported by Thapa et al.⁴¹ Because we aimed to investigate the development of chronic epilepsy, we chose not to include immediate seizures as instances of PTS. This enabled us to avoid an overestimation of seizure occurrence.¹¹

Predictors of PTE

A number of studies have shown that PTS increases the risk for PTE. Of 318 severely injured children treated during a period spanning 25 years, 21.4% experienced late PTS; of them, > 70% developed PTE, and roughly half had intractable seizures.²⁶ The authors of that study found that PTE provoked developmental disturbances and eventually resulted in poor mental outcome. Similarly, in a 10-year retrospective chart review of 130 children with severe TBI, early PTS was found to increase the risk for late PTS (and thus PTE, by our definition) by as much as 6-fold.⁶ This is similar to our study, in which 85.7% of children with PTS ultimately progressed to develop PTE.

We report a significant association between LOH at the time of injury and the development of epilepsy. Children who developed PTE spent an average of 2 more days in the hospital. Previous research showed that LOH is associated with injury severity, although this correlation is unclear in the case of mild injuries.¹² In our cohort, common reasons for increased LOH were multiple injuries (mainly long bone fractures), observation for possible CSF leak, and residency in rural areas. We believe that our findings suggest that within a given level of severity, LOH may serve as an indirect indicator of aspects of severe injury that are not covered by the GCSSOA.

Studies that examined patient age as a predictor of seizures showed contradictory results.^{4,8,39} Ratan et al. found that children < 2 years of age were at a higher risk for PTS.³⁶ In contrast, Christensen et al. found an elevated risk

for children ≥ 15 years of age.¹² Frey hypothesized that a claim of younger age as a risk factor results from failure to adjust for increased risk of seizure in this population.¹⁷ Within our cohort, younger age did not increase the risk for PTE, which supports the hypothesis presented by Frey.

Similar to previous studies that included mild injuries in their analyses,^{31,36} we did not identify specific CT features as risk factors for PTE. Previous studies have hypothesized that any damage that increases the risk for epileptic episodes may be minute and undetectable by CT in its early stages.³ This is supported by our finding that one-third of the patients who developed PTE had normal CT scans. Although not statistically significant, this highlights the value of proper clinical evaluation.

Intractable Epilepsy

The overall incidence of intractable epilepsy in the general population is approximately 0.2%.^{14,24,27} Much research and many theories have attempted to identify the mechanisms and etiologies leading to refractory epileptogenesis.^{28,32,37,38} Of note, Temkin⁴⁰ described the failure of AEDs to prevent or even suppress PTS. Furthermore, MTBI incidence was reported to be 4 times higher in 86 patients who underwent surgery for intractable epilepsy than among age- and sex-matched control subjects.²³ Nonetheless, no causal relationship has been reported. Among our patients, 3 children (1.6%) were found to suffer from epilepsy resistant to AEDs, a rate 8 times higher than in the general population. This finding significantly reinforces the hypothesized link between brain injury and intractable epilepsy.

Definitions of Basic Concepts

Definition of PTE

The definition of PTE has yet to be determined in the literature. In their study of 63 adults with moderate to severe TBI who developed late PTS, Haltiner et al.¹⁹ reported a cumulative seizure recurrence rate of 86% within 2 years. Additionally, several physiological characteristics of the developing brain induce a more excitatory state and may predispose an injured child to experience recurrent seizures.¹ These findings have prompted some to consider the first convulsive episode as part of PTE.¹³ However, recent studies by Angeleri et al.,³ Appleton and Demell-week,⁵ Statler,³⁹ and Yablon⁴² strictly define PTE as ≥ 2 seizure episodes. More importantly, many studies use these terms interchangeably.^{17,39} Because the association between PTS and recurrent PTE is ill defined in children and especially for MTBI, our study clearly distinguishes between a single seizure episode and chronic recurrence.

Definition of MTBI

In our study, MTBI was defined as a GCSSOA > 13, which, in itself, is a subject of much debate. Christensen et al. and Thapa et al. each used identical GCS categories,^{12,41} whereas Asikainen et al., Hahn et al., and Huguenard et al. included a GCS score of 13 in MTBI.^{7,18,21} Moreover, Ferguson et al. defined severity based on the Abbreviated Injury Scale,¹⁶ Lewis et al. divided the GCS into 2 categories,³¹ and Annegers et al. and Matsumoto et

al. used parameters such as imaging findings, loss of consciousness, and amnesia to determine severity.^{4,33} These inconsistencies make comparisons among studies difficult and questionable. Moreover, the exact correlation between GCS score and the biological mechanisms leading to PTE is uncertain. The classic definition of MTBI as a GCS score > 13 was shown to better predict complications and mortality, and therefore was used in our research.³⁵ Standardization is paramount for reliability and reproducibility. Therefore, future research must adhere to current GCS guidelines to create a standardized framework for comparison.

Potential Weaknesses of This Study

The reliance on children's and caregivers' recollections of the first occurrence of PTS subjects this study to recall bias. However, because an initial tonic-clonic seizure is traumatic for both child and caregiver, we believe that the chances of failing to recall its occurrence are slim. We do acknowledge that there may be inaccurate recall of the timing of the first episode. However, this would only affect our secondary PTE latency variable and not our primary outcome of PTE incidence.

Due to the observational design, we lack data from evaluations such as those using EEG and MRI, and thus cannot exclude other epileptic etiologies with complete certainty. Additional prospective research may elucidate the role of these imaging modalities in the ongoing management of children with PTE. Because we focused on children admitted to the hospital, we cannot extend our results to those who do not present to, or who are discharged from, the ED.

Finally, due to the nature of long-term follow-up, approximately one-third of patients were unattainable for telephone survey. Although this raises the possibility of information bias, demographic data and clinical characteristics of patients who did and did not respond were similar. Moreover, our participation rate was high compared with other long-term follow-up studies of similar populations, which were in the range of 1%–31%.^{16,21} Notably, other studies may have presented better participation rates by implementing stricter exclusion criteria, yet this creates selection bias.

Conclusions

To our knowledge, this is the first long-term follow-up study to distinctly focus on epilepsy, rather than on convulsive episodes, in children admitted for MTBI. The rate of PTE after MTBI was 3.1%, with a mean latency period of 3 years. The risk for a child with MTBI to develop intractable epilepsy was 8 times higher than in the general population. Contrary to current assumptions, neither immediate PTS nor specific CT findings seem to play a role in predicting the risk for PTE after MTBI in children. This highlights the need for solid clinical assessment at initial presentation and upon admission, with particular awareness of the increased risk for PTS and PTE even in the settings of MTBI. Closer monitoring is justified to facilitate early detection of epileptic complications in this group. Whether this should be accomplished by regular outpa-

tient clinics or EEG is to be determined. Strict definitions of TBI severity must be made to enable evaluation of the cumulative research on this subject.

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Disclosures

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Author Contributions

Conception and design: Benifla, Keret. Acquisition of data: Benifla, Keret. Analysis and interpretation of data: all authors. Drafting the article: Benifla, Keret, Bennett-Back. Critically revising the article: Benifla, Keret, Bennett-Back. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Benifla. Statistical analysis: Benifla, Keret. Administrative/technical/material support: Benifla, Keret. Study supervision: Benifla, Keret.

Correspondence

Mony Benifla, Department of Neurosurgery, Hadassah Medical Center, PO Box 12000, Jerusalem 91120, Israel. email: beniflam@yahoo.com.