

Prevalence of and Risk Factors for Poor Functioning after Isolated Mild Traumatic Brain Injury in Children

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Abstract

This study aimed to determine the prevalence and predictors of poor 3 and 12 month quality of life outcomes in a cohort of pediatric patients with isolated mild TBI. We conducted a prospective cohort study of children and adolescents < 18 years of age treated for an isolated mild TBI, defined as “no radiographically apparent intracranial injury” or “an isolated skull fracture, and no other clinically significant non-brain injuries.” The main outcome measure was the change in quality of life from baseline at 3 and 12 months following injury, as measured by the Pediatric Quality of Life index (PedsQL). Poor functioning was defined as a decrease in total PedsQL score of > 15 points between baseline and follow-up scores (at 3 and 12 months). Of the 329 patients who met inclusion criteria, 11.3% (95% CI 8.3–15.3%) at 3 months and 12.9% (95% CI 9.6–17.2%) at 12 months following injury had relatively poor functioning. Significant predictors of poor functioning included less parental education, Hispanic ethnicity (at 3 months following injury, but not at 12 months); low household income (at 3 and 12 months), and Medicaid insurance (at 12 months only). Children and adolescents sustaining a mild TBI who are socioeconomically disadvantaged may require additional intervention to mitigate the effects of mild TBI on their functioning.

Key words: epidemiology; outcome measures; prospective study; pediatric brain injury

Introduction

ALTHOUGH TRAUMATIC BRAIN INJURY (TBI) is the leading cause of death in children, ~ 75–97% of TBIs have been characterized as “mild.”^{1–3} While moderate and severe TBIs in children result in more significant long-term functional disability,^{3,4} there is emerging evidence that, for some patients, mild TBI can lead to prolonged physical and neurocognitive symptoms months to years after injury.^{5–7} However, it is still unclear how these persistent symptoms translate into everyday quality of life, and how common poor overall functioning is following mild TBI.

Although many prior studies have examined longer-term outcomes following pediatric mild TBI, there is significant heterogeneity in injury severity definition, methodological approach and rigor, outcome measures, and results.⁸ Less is known about outcomes of mild TBI across a wide age range of children and adolescents, and in whom outcomes are measured in multiple dimensions over time.⁸ The aim of this study was to determine the prevalence and predictors of poor functioning as defined by large declines from baseline in 3 and 12 month Pediatric Quality of Life

Inventory (PedsQL) scores in a cohort of pediatric patients with isolated mild TBI.

Methods

Patient population

As described in previous reports of the Child Health After Injury (CHAI) Study,^{2,3} we identified all subjects < 18 years of age treated for a TBI either in the emergency department (ED) or as inpatient at nine participating institutions in King County, Washington and one in Philadelphia, Pennsylvania. Study informants were consenting parents or guardians of subjects randomly selected from the list of all eligible subjects treated between March 1, 2007, and September 30, 2008, who were contacted and agreed to be in the study. Adolescent subjects ≥ 14 years of age at the time of follow-up also completed separate surveys. The human subjects committees of participating institutions approved all study procedures.

Definition of isolated mild traumatic brain injury

We used the definition of TBI described in the 2002 Centers for Disease Control and Prevention (CDC) report:⁹ an injury to the

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head that was documented in the medical record, with at least one of the following conditions attributed to brain injury: observed or reported decreased level of consciousness, amnesia, or objective neurological or neuropsychological abnormality, or a diagnosis of intracranial lesion. Mild TBI was based on both the CDC¹ and World Health Organization (WHO)¹⁰ criteria, and was defined as: any period of transient confusion, disorientation, impaired consciousness, or amnesia lasting < 24 h, or signs of other neurological or neuropsychological dysfunction, with the worst Glasgow Coma Scale (GCS) score of 13–15 at initial evaluation, and GCS score of 15 at discharge from the emergency department or at 24 h post-injury if hospitalized. Mild TBI was further subclassified into: mild I, no abnormalities on CT scans, or patients in whom CT scans were not performed who met criteria for mild TBI; mild II, skull fracture without intracranial hemorrhage; and mild III, intracranial hemorrhage, and meeting criteria for mild TBI. Only patients with mild I and mild II were included in this analysis. In order to consider only those with isolated mild TBI, patients were excluded if they had a non-brain injury with an Abbreviated Injury Scale (AIS)¹¹ score of ≥ 2 (which indicated a clinically significant injury that could have affected outcomes). The AIS is a standard, categorical injury scale from 1 to 6, where 1 is “minor,” and 6 is “maximal, currently untreatable.” Patients were also excluded if the injury was intentional or if they had had a prior TBI by self-report.

Procedures

A baseline telephone survey that gathered information about the subject's pre-injury status was administered as soon as possible after the injury to one parent or guardian, and to adolescent patients ≥ 14 years of age. Follow-up surveys were conducted 3 and 12 months after the date of the index injury. In addition to the standardized measures described subsequently, data on self-reported race/ethnicity, insurance status, household income, and respondent education were collected.

Measures

The PedsQL is a measure of health-related quality of life that assesses physical, emotional, social, and school functioning of children. The PedsQL has been found to be reliable and valid, including for children with TBI.^{4,12–14} Total PedsQL scores range from 0 to 100, with higher scores indicating higher quality of life. Poor functioning was defined as a decrease in total PedsQL score of > 15 from baseline to 3 and 12 months, respectively. This definition of patients with significantly worse outcomes has been previously shown to correspond to the approximate mean difference on the PedsQL between normal children and those with a moderately severe chronic health condition.^{15,16} The remainder of the patients in the sample were considered to have “expected” outcomes. The PedsQL was only available for children ≥ 2 years of age at the time of the assessment.

Other scales measured that were assessed as potentially associated with poor functioning included: a headache scale previously described using the same data set,¹⁷ the sleep subcomponent of the PedsQL,¹⁸ depressive symptoms from the Patient Health Questionnaire (PHQ-9),¹⁹ and the University of California at Los Angeles (UCLA) Reaction Index, a post-traumatic stress disorder (PTSD) checklist.²⁰

Other measures in the baseline survey included child, parental, and family demographic information; the subject's pre-injury medical history; and an assessment of family functioning using the McMaster Family Assessment Device.

Medical record data

Charts were comprehensively abstracted by the principal investigator (Dr. Rivara) or a trained research nurse using an online standardized abstraction form. These abstractors were blinded to the baseline and outcome measures.

Statistical analysis

Demographic and clinical characteristics of subjects with expected versus poor functioning were compared using χ^2 or Fisher's exact test for categorical variables, and *t* test statistics for continuous variables, to assess for significant differences.

Linear mixed models were developed to assess the change of PedsQL score from baseline to 3 months or 12 months in patients with expected outcomes compared with those with poor outcomes. The models for both groups and both time periods were adjusted for age, gender, child race, family income, and parent/guardian education.

Analyses were conducted using SAS 9.2 (SAS Institute Inc., Cary, NC) data analysis software.

Results

There were 329 patients who met the inclusion criteria, of whom one was missing the 3 month PedsQL score, and 18 were missing 12 month PedsQL scores. The mean PedsQL score for the entire sample was 86.5 (range 23.2–100) at baseline; 83.3 (range 25–100) at 3 months, and 83.0 (range 25.9–100) at 12 months post-injury. Poor functioning, as defined, was seen in 11.3% (95% CI 8.3–15.3%) of the patients at 3 months following injury and 12.9% (95% CI 9.6–17.2%) of the patients at 12 months following injury. Figure 1 shows the distribution of the change in PedsQL scores between baseline and 3 months, and baseline and 12 months.

Table 1 compares the baseline characteristics of the mild TBI patients with expected outcomes and poor outcomes, and Table 2 compares the injury-related characteristics. Poor functioning was significantly associated with: older age (RR[95% CI]=1.006[1.001,1.011] per year of age) at 3 months, Hispanic ethnicity versus white non-Hispanic (RR[95% CI]=3.37[1.47, 7.73]) at 3 months, less than high school parental education versus post-college (RR[95% CI]=4.44[1.55,12.76]) at 3 months, some college versus post-college (RR[95% CI]=2.51[1.03,6.10]) at 12 months, and Medicaid insurance versus private insurance (RR[95% CI]=2.22[1.21,4.06]) at 12 months, and low annual household income of $< \$30,000$ versus $> \$100,000$ (RR[95% CI]=2.73[1.28, 5.83], 3.10[1.40,6.86]) at 3 and 12 months respectively, and $\$60,000$ – $\$100,000$ versus $> \$100,000$ (RR[95% CI]=2.51[1.14, 5.53]) at 12 months only.

Table 3 shows the mean PedsQL scores at baseline, 3 months, and 12 months, as well as the change and adjusted change in score from baseline to 3 months and baseline to 12 months. Subjects with poor outcomes had ~ 14 – 24 points lower in the adjusted change in PedsQL scores than did those with expected outcomes.

There were no significant differences at pre-injury baseline between the two groups on trouble sleeping, headache, or depressive symptoms. Subjects who had trouble sleeping “sometimes, often, or almost always” at 3 months and “often or almost always” at 12 months, were more likely to have poor outcomes at 3 and 12 months, respectively ($p < 0.0001$ for both comparisons). Similarly, subjects who had headache or other pain symptoms at 3 months and 12 months were also more likely to have poor outcomes at 3 and 12 months, respectively ($p < 0.05$ for both comparisons). Depressive symptoms and PTSD symptoms were not associated with poor outcomes at either the 3 or 12 month time period.

Patients with poor outcomes were more likely to have lower mean absolute PedsQL scores across all four subdomains (physical, social, school, cognitive) at the 3 and 12 month time period compared than were those with expected outcomes ($p < 0.001$ for all comparisons).

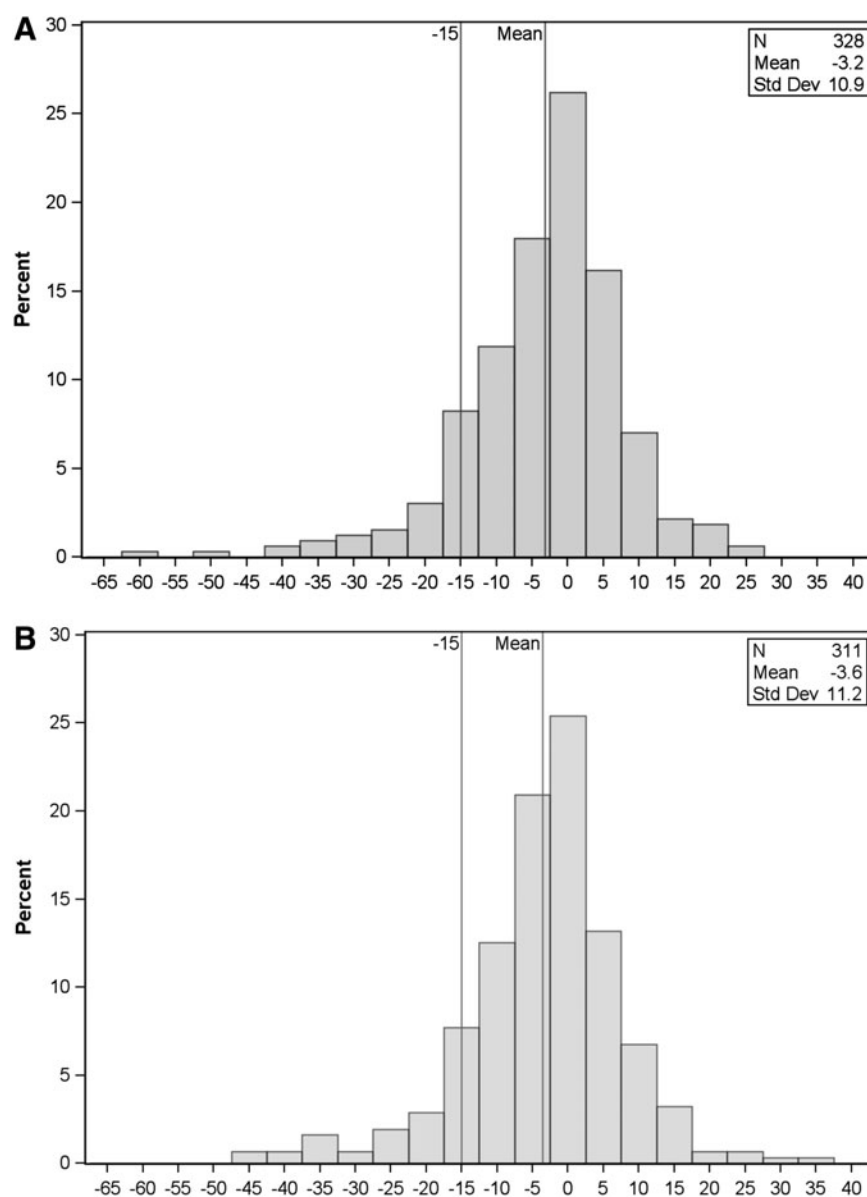


FIG. 1. (A) The distribution of the change in Pediatric Quality of Life Index (PedsQL) score between baseline and 3 months following injury. (B) The distribution of the change in PedsQL score between baseline and 12 months following injury.

Discussion

This large study of the prevalence and predictors of low PedsQL scores in a cohort of patients with isolated, mild TBI found that ~12% of subjects with mild TBI had poor quality of life at 3 and 12 months following their injury. Patients who were socioeconomically disadvantaged were more likely to have poor outcomes at 3 and/or 12 months following injury, across all domains of the PedsQL. Our prior work using the full cohort found that subjects with mild TBI overall generally had good outcomes over time as measured by average PedsQL scores, particularly when compared with those with moderate and severe TBI. However, averages obscure the full range of PedsQL scores among those with mild TBI.³ Therefore, those with poor functioning were “hidden” in the larger group.

The mean absolute total PedsQL scores for subjects with expected outcomes at 3 and 12 months were 85.8 and 85.6, respec-

tively, whereas those for subjects with poor outcomes were 63.8 and 66.1, respectively. This is comparable to prior pediatric TBI research in which parents’ subjective measurement of their child’s cognition being “somewhat worse” at 3 and 12 months following injury corresponded to a mean total PedsQL score of 66.4.²¹ Interestingly, the clinical definition of poor outcomes (decrease in total PedsQL score of > 15 from baseline to follow-up) based on prior literature¹⁵ approximated a change in PedsQL of > 1 standard deviation (SD) below the mean difference (Fig. 1). Other work has shown poor quality of life at 1 SD below the absolute mean PedsQL score.¹⁶

According to the AIS scoring system, an AIS 1 injury is “minor,”¹¹ with a very low risk of fatality. In the most recent version of the AIS manual (AIS 2005, Update 2008), concussion without loss of consciousness is an AIS 1 injury. Although AIS was originally designed as a “threat to life scale,” the morbidity associated with nonfatal injuries is also routinely measured with the instrument.

TABLE 1. CHARACTERISTICS OF THE MILD TBI STUDY POPULATION

	Baseline total mean PedsQL score	3 month PedsQL				12 month PedsQL			
		n	Expected n=291 Row%	Poor ^a n=37 Row%	p value	n	Expected n=271 Row%	Poor ^a n=40 Row%	p value
Age at injury					0.002				0.33
0–4 years	91.2	62	95.2	4.8		57	93.0	7.0	
5–9 years	85.6	108	93.5	6.5		104	87.5	12.5	
10–14 years	85.3	105	79.1	20.9		99	82.8	17.2	
15–17 years	85.2	53	90.6	9.4		51	88.2	11.8	
Gender					0.09				0.92
Male	85.9	210	91.0	9.0		200	87.0	13.0	
Female	87.6	118	84.8	15.2		111	87.4	12.6	
Race/ethnicity					0.11				0.65
White, non-Hispanic	86.4	237	90.7	9.3		230	87.8	12.2	
Black, non-Hispanic	86.0	7	85.7	14.3		7	71.4	28.6	
Hispanic	91.4	16	68.8	31.2		12	83.3	16.7	
Asian	85.1	5	100	0		5	100	0	
Other or multiple	86.0	61	85.3	14.7		55	85.5	14.5	
Unknown	83.6	2	100	0		2	100	0	
Health insurance					0.12				0.07
None	88.5	8	75.0	25.0		8	87.5	12.5	
Medicaid	83.8	76	82.9	17.1		67	77.6	22.4	
Private	87.3	216	90.7	9.3		208	89.9	10.1	
Unknown	86.8	28	92.9	7.1		28	89.3	10.7	
Household income					0.02				0.04
< \$30,000	81.8	56	78.6	21.4		49	77.6	22.4	
\$30,000–\$60,000	84.8	47	83.0	17.0		44	86.4	13.6	
> \$60,000–\$100,000	86.5	71	91.6	8.4		66	81.8	18.2	
> \$100,000	88.7	140	92.1	7.9		138	92.8	7.2	
Unknown	89.5	14	100	0		14	92.9	7.1	
Respondent education					0.02				0.25
Less than high school	84.2	15	66.7	33.3		11	90.9	9.1	
High school, GED	83.7	34	91.2	8.8		32	90.6	9.4	
Some college	85.2	90	84.4	15.6		83	80.7	19.3	
College graduate	88.5	109	91.7	8.3		107	86.9	13.1	
Post-college	86.8	80	92.5	7.5		78	92.3	7.7	
Family Assessment Device baseline, mean score (SD)	86.5	328	17.8 (5.1)	17.9 (4.2)	0.94	311	17.8 (4.9)	17.6 (6.1)	0.89
Pre-injury comorbidities ^b					0.33				0.24
None	91.7	102	91.2	8.8		95	91.6	8.4	
1	88.6	90	90.0	10.0		88	88.6	11.4	
2	87.7	60	90.0	10.0		58	84.5	15.5	
≥ 3	76.3	76	82.9	17.1		70	81.4	18.6	

^aDefined by a decrease in total PedsQL score of >15 points from baseline to follow-up.

^bPre-injury comorbidities assessed included developmental delay, seizures, hemiplegia or paraplegia, lung disease, diabetes, attention-deficit/hyperactivity disorder, depression, other mental health or behavioral problems, learning problems, previous fractures, and previous surgery. TBI, traumatic brain injury; PedsQL, Pediatric Quality of Life Index.

Given the persistent disability of those in this study with seemingly “mild” injuries, use of the AIS system to accurately categorize severity of injury for certain injuries may need to be reconsidered.²²

Of the 40 patients with poor outcomes at 12 months, 20 (50%) did not have poor outcomes at 3 months. There are a few possible explanations. First, subjects could have sustained an additional injury during the follow-up period, which was not captured in our data collection. Another possibility is that symptoms actually do increase over time, leading to poorer quality of life measures. This was observed in a recent study of children and adolescents 8–15 years old with mild TBI who had increases in post-concussive

symptoms and impaired functionality up to 1 year following injury.⁷ There is a growing body of literature demonstrating that providers who care for children with mild TBI, including concussion, may not be consistently recognizing symptoms or providing evidence-based treatment.²³

Our work is consistent with prior studies showing disparities in mortality and long-term functionality following more severe TBI, with disadvantaged youth and patients with inflicted brain injury having poorer outcomes.^{24–27} These studies emphasize the need to further identify causes of such outcomes, such as disparities in care, variable compliance with recovery plans, and the lack of social support in these populations.

TABLE 2. INJURY CHARACTERISTICS FROM MEDICAL RECORD ABSTRACTION

	n	3 month PedsQL			12 month PedsQL			
		Expected n = 291 Row%	Poor ^a n = 37 Row%	p value	n	Expected n = 271 Row%	Poor ^a n = 40 Row%	p value
Mild TBI				0.74				0.49
1	306	88.6	11.4		290	86.6	13.4	
2	22	90.9	9.1		21	95.2	4.8	
Mechanism of injury				0.84				0.26
Motor vehicle (occupant)	11	81.8	18.2		11	72.7	27.3	
Pedestrian or bicycle	25	92.0	8.0		23	78.3	21.7	
Fall	189	88.9	11.1		178	88.2	11.8	
Stuck by/against	102	88.2	11.8		98	88.8	11.2	
Emergency medical services level				0.30				0.56
Advanced life support	21	81.0	19.0		20	80.0	20.0	
Basic life support	40	85.0	15.0		37	89.2	10.8	
Not transported by emergency medical services	259	89.6	10.4		246	87.4	12.6	
Isolated TBI	221	89.1	10.9	0.73	208	87.5	12.5	0.79
Head maximum AIS				0.51				0.21
1	230	90.0	10.0		219	89.0	11.0	
2	86	86.1	13.9		81	81.5	18.5	
3	12	83.3	16.7		11	90.9	9.1	

^aDefined by a decrease in total PedsQL score of > 15 points from baseline to follow-up.

TBI, traumatic brain injury; PedsQL, Pediatric Quality of Life Index; AIS, Abbreviated Injury Scale score.

There are some limitations of this study worth noting. Self-reported measures of functionality may not consistently be accurate, although the PedsQL has proven valid and reliable for a variety of disease states and severities.¹² Although not all subjects in this mild TBI group had a head CT scan completed immediately following their injury, the rate of CT use in the poor outcome group was similar to that in the expected outcome group. Another potential limitation is that follow-up surveys did not inquire about re-injury (TBI or otherwise), which could contribute to lower PedsQL scores at follow-up. However, it is unlikely that re-injury could account for the entire proportion of patients with poor outcomes. Finally, the definition of poor functioning using a decrease of > 15 total PedsQL points may not have captured all of the subjects with clinically relevant poor quality of life, and, therefore, likely results

in a conservative estimate of the prevalence of poor functioning following mild TBI.

In addition to maximizing acute care, health care providers should ensure that multidimensional support and resources are available, particularly for patients who are at risk for poorer outcomes. Finally, primary prevention should always be considered as a means of minimizing the burden of mild TBI. Regular anticipatory guidance surrounding child passenger safety in motor vehicles, injury prevention in the home, and recreational safety is paramount. Attention should be focused on children and adolescents who are socioeconomically disadvantaged, and who have premorbid conditions that may predispose them to TBI or prolong their recovery.

Future work should focus on identifying additional risk factors for poor outcomes following mild TBI, and improved ascertainment

TABLE 3. SCORES ON THE PEDIATRIC QUALITY OF LIFE (PedsQL) SCALE TOTAL SCORE FOR CHILDREN AND ADOLESCENTS WITH MILD TBI 1 OR MILD TBI 2, AND WITH A NON-HEAD MAXIMUM AIS OF < 2

	Mean at month			Δ^b	Change 0→3 months				Δ^b	Change 0→12 months			
	0	3	12		95% CI	Diff ^b	95% CI	95% CI		Diff ^b	95% CI	Diff ^b	95% CI
n	328	328	310										
Expected outcomes at 3 months	86.3	85.8	84.7	-0.5	-1.4, 0.4	Ref			-1.7	-2.8, -0.7	Ref		
Poor outcomes ^a at 3 months	88.4	63.8	70.0	-24.6	-27.8, -21.3	-24.1	-27.4, -20.7		-18.1	-23.2, -13.0	-16.4	-21.6, -11.1	
n	311	310	311										
Expected outcomes at 12 months	86.1	84.7	85.6	-1.4	-2.5, -0.4	Ref			-0.5	-1.5, 0.4	Ref		
Poor outcomes ^b at 12 months	90.0	75.1	66.1	-15.0	-19.4, -10.6	-13.5	-18.1, -9.0		-23.9	-26.7, -21.2	-23.4	-26.3, -20.5	

^aDefined by a decrease in total PedsQL score of > 15 points from baseline to follow-up.

^bAdjusted for age, gender, child race, family income, and parent education.

TBI, traumatic brain injury; AIS, Abbreviated Injury Scale score.

about re-injury in longitudinal TBI studies, as well as improved diagnostics for patients with “mild” TBI, such as biomarkers or advanced non-radiating diagnostic imaging. In addition, providers who care for patients with mild TBI should consider adapting standardized protocols for the evaluation of and treatment of mild TBI,²⁸ and testing the efficacy of these treatments with trials.

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Author Disclosure Statement

No competing financial interests exist.

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