

Intellectual, Behavioral, and Social Outcomes of Accidental Traumatic Brain Injury in Early Childhood



WHAT'S KNOWN ON THIS SUBJECT: Traumatic brain injury in school-aged children is associated with intellectual, behavioral, and social deficits. Research into outcomes of children injured before 3 years of age is limited despite data suggesting a high incidence of injury in this age group.



WHAT THIS STUDY ADDS: Results show that a moderate to severe traumatic brain injury before 3 years of age is associated with lowered cognitive function. Furthermore, this study highlights the link between social disadvantage and poor outcomes after traumatic brain injury in early childhood.

abstract

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OBJECTIVE: The intellectual, behavioral, and social function of children who sustained traumatic brain injury (TBI) before 3 years of age were compared with a group of uninjured children. The role of injury and environmental factors in recovery was examined.

METHODS: A group of 53 children who sustained a TBI before 3 years of age (20 mild and 33 moderate/severe) and 27 uninjured children (control group) were assessed on an IQ measure and parent measures of behavior and social skills. Children were aged 4 to 6 years and were an average of 40 months since sustaining their injury.

RESULTS: There were no demographic differences between the groups. Although all group scores were in the average range, children with moderate/severe TBI performed significantly below uninjured children on an IQ measure. No significant differences were found on parent behavior ratings, although effect sizes between groups were medium to large. No differences were found for social skills. All outcomes were significantly influenced by environmental but not injury factors.

CONCLUSIONS: Moderate/severe TBI at an early age appears to be associated with lowered intellectual function and possibly behavior problems. A child's environment influences cognitive and behavior function after TBI. *Pediatrics* 2012;129:e262–e268

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KEY WORDS

traumatic brain injury, children, infants, intellectual functioning

ABBREVIATIONS

ANOVA—analysis of variance

CBCL—Child Behavior Checklist

FSIQ—full-scale IQ

GCS—Glasgow Coma Scale

K6—Kessler 6 Scale

PIQ—performance IQ

SES—socioeconomic status

SSRS—Social Skills Rating Scale

TBI—traumatic brain injury

VIQ—verbal IQ

WPPSI-III—Wechsler Preschool and Primary School Scale of Intelligence-III

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Traumatic brain injury (TBI) is a major cause of death and disability in children¹ and children <3 years of age have a particularly high incidence of TBI.^{2–4} The majority of research into the outcomes of TBI in children <3 years of age has either focused on the outcomes of inflicted TBI^{5–7} or combined inflicted and accidental TBI.^{8,9} Children with inflicted TBI tend to have poorer outcomes than children with accidental TBI,¹⁰ on account of both neurologic and environmental differences.^{11,12} Research studies into recovery after accidental TBI in this age group are limited, despite that most TBI in this age group are due to accidental causes.¹³

Young children are at elevated risk of brain damage after accidental TBI for the following reasons: an increase in diffuse injury possibly due to the thin and pliable skull necessary for birth^{14,15}; a disproportionately large and heavy head with weak neck muscles increasing infants' susceptibility to rotational and shearing forces^{13–15}; and elasticity of blood vessels.¹⁴ Significant brain damage including mass lesion, subdural hematoma, and tears in the subcortical white matter of the frontal lobes all occur more often after TBI in children <3 years of age at injury than in older children.¹³ The increased vulnerability of the young child's brain to TBI means that abilities commonly disrupted by TBI at an older age, such as intellectual, behavioral, and social function, may be even more impaired with younger age at injury. Young children have few, if any, established skills, and thus damage to the brain is likely to impair their ability to acquire skills at the same rate as uninjured children.¹⁶

It is well established that TBI in older children results in ongoing cognitive impairments, with lowered IQ consistently found.^{17,18} There is far less research describing cognitive outcomes of children injured before 3 years of age. Research available for this age

demonstrate lowered verbal IQ (VIQ), performance IQ (PIQ), and full-scale IQ (FSIQ),^{8,19,20} as well as behavior problems.²¹ Behavior problems identified include hyperactivity, conduct problems, poor self-control, and internalizing difficulties.^{21,22} Few studies have investigated the impact of early childhood TBI on social skills. In children who sustained a TBI in the preschool years (3–6 years), poor theory of mind,²³ and significant isolation and social difficulties²⁴ have been identified. A recent study reported that children injured before 4 years of age had greater social difficulties than children injured after this age.²⁵

Previous research has shown that injury severity, socioeconomic status (SES), family function, and parental mental health all significantly impact a child's recovery from TBI.^{26–29} For children injured at preschool age, the family environment was the strongest predictor of behavioral and social function.^{29,30} For children <3 years at TBI, little is known about the contribution of environment; nevertheless, it is clear from studies on older children that these areas must be considered when investigating outcome from TBI.

The purpose of this study was to investigate the outcome of accidental TBI in children <3 years of age. The role of injury and environmental factors in the intellectual, behavioral, and social outcomes of children post-TBI was also examined. It was anticipated that, consistent with previous research, (1) children with severe TBI would show the lowest cognitive function, (2) children with TBI would display more behavior and social deficits, and (3) both injury and environmental factors would contribute to outcome.

METHODS

Participants

This study included 80 children, 53 with a TBI before 3 years of age and 27 uninjured children who formed the control

group. Children with a TBI were recruited through attendance at the emergency department or admission to the intensive care unit of the Royal Children's Hospital, Melbourne, Australia. Children were aged 6 days to 2 years 11 months at the time of injury; English was their primary language. Inclusion criteria were as follows: (1) accidental TBI; (2) attendance at the hospital <24 hours after TBI; (3) sufficient medical records describing TBI cause, including modified Glasgow Coma Score (GCS)³¹ and radiology results; and (4) no pre- or co-existing genetic, physical, or neurologic disorder. The GCS modified for children takes into account the language abilities of children <3 years of age. Specifically, the verbal items are replaced by questions about crying and interactions with parents.³¹ At the time of the assessment, children were aged from 4 years 0 months to 5 years 11 months and were at least 2 years postinjury. Refer to Tables 1 and 2 for more information.

In line with ethics procedures, eligible families were sent a letter inviting them to participate. Children completed the assessment with a psychology researcher in 1 session, and 1 parent completed the questionnaires. The study was approved by the Human Research Ethics Committee of the Royal Children's Hospital, Melbourne, Australia.

Children were categorized into TBI severity groups by using the following criteria: mild TBI ($n = 20$), lowest modified GCS 13 to 15, indicating altered consciousness (eg, drowsy), no evidence of mass lesion on computed tomography if completed, and no neurologic deficits; moderate TBI ($n = 26$), lowest modified GCS 9 to 12, indicating significant alteration in consciousness and reduced responsiveness) and/or mass lesion or other evidence of specific injury on imaging; severe TBI ($n = 7$), lowest modified GCS 3 to 8, representing coma and mass lesion or other evidence of specific injury on imaging.

TABLE 1 Demographic Information on the 3 Groups

	Mild TBI	Moderate/Severe TBI	Control
No. of participants	20	33	27
Gender, <i>n</i> (%) male	11 (55.0)	17 (53.1)	11 (40.7)
Age at assessment in months, mean (SD) [range]	64.5 (5.6) [55–71]	60.3 (6.6) [46–70]	61.8 (6.7) [50–72]
Parent occupation skill level, mean (SD)	1.8 (1.4)	2.1 (1.4)	1.9 (1.1)
Intact family unit, <i>n</i> (%)	15 (83.3)	29 (90.6)	25 (100.0)
K6 total score	7.9 (6.1)	8.6 (6.4)	7.9 (2.86)

TABLE 2 Injury and Medical Characteristics of the 2 TBI Groups

	Mild TBI (<i>n</i> = 20)	Moderate/Severe TBI (<i>n</i> = 33)
Age at injury (months), mean (SD) [range]	17.7 (10.7) [1–35]	21.5 (12.1) [0–35]
Time since injury (months), mean (SD) [range]	46.8 (9.7) [29–64]	39.2 (9.6) [24–56]
Injury cause		
Falls, <i>n</i> (%)	18 (90.0)	22 (66.7)
Pedestrian, MVA, <i>n</i> (%)	—	3 (9.1)
Passenger, MVA, <i>n</i> (%)	—	5 (15.1)
Other, <i>n</i> (%)	2 (10.0)	3 (9.1)
Medical characteristics		
Abnormal CT, <i>n</i> (%) ^b	—	25 (75.7)
Loss of consciousness > 1 h ^b	—	10 (30.3)
GCS on admission, mean (SD) ^b	14.4 (0.9)	9.2 (3.3)

MVA, motor vehicle accident; CT, computed tomography.

Because of the small number of children with severe TBI, moderate and severe TBI patients were assessed together (*n* = 33).

The control group comprised 27 children (Table 1). The control group was recruited by both the friend-control method and from advertisements in kindergartens in the hospital catchment area. The friend-control method involved asking the families of TBI children if they had a friend with a child of the same age who might be willing to participate. Children were excluded from the control group if they had a previous TBI, any neurologic or psychological disorder, or English as a second language.

Measures

Demographic, Injury, and Family Variables

The following information was collected: gender, date of birth, injury date, cause, and location, modified GCS on arrival at the hospital, imaging results, and medical variables (eg, loss of consciousness, clinical symptoms, etc). SES was classified by the Australian

and New Zealand Standard Classification of Occupations³² system, which is published by the Australian government and classifies occupations into 5 levels (1 is the highest), taking into account the level of formal education and training required, the amount of previous experience in a related occupation, and the amount of on-the-job training. The highest skill level of both parent occupations was used.

Family function was assessed by using the Family Functioning Questionnaire,³³ which contains 68 items and has 3 factors: intimacy, conflict, and parenting style. The intimacy factor was used in analyses because it has a high correlation with the other factors and has previously been used as a measure of family cohesion in TBI studies.²⁷

The Kessler 6 Scale (K6)³⁴ was used to measure parent mental health. It measures nonspecific psychological distress by the use of 6 symptoms and level of functional impairment in the previous month. A total score is calculated, with a score >19 indicating significant psychological distress.

Child Measures

Cognitive, behavioral, and social function scores were taken from a larger study investigating many areas of function not described in this article, including executive function, attention, and receptive and expressive language.

Cognitive Function

The Wechsler Preschool and Primary School Intelligence Scale-Third Edition (WPPSI-III)³⁵ was administered to all children. VIQ, PIQ, and FSIQ were calculated (mean = 100, SD = 15). The coding subtest was administered as a measure of processing speed (mean = 10, SD = 3).

Behavioral and Social Function

The Child Behavior Checklist for children aged 1.5 to 5 years (CBCL)³⁶ is a parent-rating scale of children's behavior with the following subscales: emotionally reactive, anxious/depressed, somatic complaints, withdrawn, sleep problems, attention problems, aggressive behavior, and other problems. It also has summary scores: internalizing behavior, externalizing behavior, and total behavior score (mean = 50, SD = 10).

The Social Skills Rating System—Preschool version (SSRS)³⁷ is a parent-rating scale of social skills. There are subscale scores for cooperation, assertion, responsibility, and self-control. Raw scores were converted to behavior levels of fewer (0–10), average (11–17), and more (18–20). The total standard score (mean = 100, SD = 15) was also calculated.

The CBCL and SSRS were added to the protocol after study commencement (CBCL first, SSRS second); therefore, a smaller number of families completed these questionnaires. All families who enrolled after this point completed the questionnaires.

Statistical Analysis

The 3 groups were compared on demographic factors (gender, age at

assessment, SES) by using χ^2 analysis and analysis of variance (ANOVA), as appropriate, to test for group differences. χ^2 analysis and ANOVA were also conducted to test for group differences for the 2 TBI groups. To investigate group differences on the IQ and parent-rating scales, scaled scores and *t*-scores were compared by using multivariate ANOVA with follow-up ANOVA and post hoc testing (Tukey honestly significant difference test). Effect sizes were calculated using the Cohen *d* and were defined as “small, *d* = 0.2, medium, *d* = 0.5,” and large, *d* = 0.8”.³⁸ The number of children in the impaired range was compared across the groups for IQ, behavior, and social measures by using χ^2 analysis. Impaired was defined as WPPSI-III and SSRS score of <85 (equivalent to 1 SD below mean) and the CBCL score of >65 (clinical range). Hierarchical regression analysis was used to determine predictors of outcome. SES was entered at step 1 and lowest GCS 24 hours, family function, and parent mental health entered at step 2. The SES measure is an ordinal variable that was treated as a metric in the regression analysis.

RESULTS

Demographic and Injury Variables

No significant differences were found between the 3 groups for gender, SES, age at assessment, number of intact households, or parent K6 total score as presented in Tables 1 and 2. Table 2 shows that the majority of injuries for both the TBI groups occurred as a result of falls. Other medical variables were distributed as expected, with more significant injury indicated for the moderate/severe group. There were no group differences for age at injury or time since injury.

Intellectual Outcomes

IQ scores for the 3 groups are presented in Table 3.

Visual inspection of the data indicated that the moderate/severe group were below the control and mild TBI groups, although still in the average range. The difference between the groups was significant overall, Wilks Δ = 0.83, $F(6144) = 2.36$, $P = .030$, with significant differences for VIQ, $F(2,76) = 3.35$, $P = .041$; PIQ, $F(2,76) = 4.47$, $P = .015$; and FSIQ, $F(2,76) = 3.38$, $P = .039$. Post hoc testing revealed that the moderate/severe group had significantly lower scores than the control group, with large effect sizes between these groups. More children in the moderate/severe group ($n = 6$, 20%) were in the impaired range for PIQ, $\chi^2(2) = 6.11$, $P = .04$, than expected (SR = 1.7).

Coding from the WPPSI-III was used to measure processing speed. There

were no significant group differences, $F(2,48) = 0.36$, $P = .69$, and small effect sizes.

Behavioral and Social Outcomes

Data from the CBCL and SSRS were available for a subset of the total group (CBCL $n = 52$; SSRS $n = 43$). Refer to Table 4 for mean scores and effect sizes.

Visual inspection of the data shows that children in the TBI groups had higher T-scores, indicative of greater behavioral dysfunction, but no significant group differences were found for the CBCL subscales, Wilks Δ = 0.79, $F(14, 86) = 0.77$, $P = .69$. Medium effect sizes were identified between the control and mild TBI group for emotionally reactive, withdrawn, and attention problems.

TABLE 3 IQ Scores Across the 3 Groups

	Mild TBI (<i>n</i> = 20)	Moderate/Severe TBI (<i>n</i> = 33)	Control (<i>n</i> = 27)	Effect size (<i>d</i>) Mild TBI versus M/S TBI Control versus Mild TBI Control versus M/S TBI
VIQ, mean (SD) ^a	98.40 (10.85)	94.50 (9.70)	101.37 (9.58)	0.37, 0.29, 0.70
PIQ, mean (SD) ^a	102.20 (11.46)	97.23 (13.02)	107.04 (9.43)	0.37, 0.45, 0.78
FSIQ, mean (SD) ^a	99.65 (10.13)	96.13 (12.67)	103.70 (9.41)	0.31, 0.41, 0.68
Coding subtest, mean (SD)	9.84 (2.43)	10.50 (3.25)	10.50 (2.38)	−0.23, 0.27, 0.00

M/S, moderate/severe group.

^a Significant difference between the groups.

TABLE 4 CBCL and SSRS Scores Across the 3 Groups

	Mild TBI, Mean (SD)	Moderate/Severe TBI, Mean (SD)	Control, Mean (SD)	Effect size (<i>d</i>) Mild versus M/S, Control versus Mild, Control versus M/S
CBCL clinical scales	<i>n</i> = 19	<i>n</i> = 15	<i>n</i> = 18	
Emotionally reactive	54.00 (7.17)	52.67 (6.09)	51.00 (2.84)	0.20, 0.55, 0.35
Anxious/depressed	52.78 (5.79)	53.00 (4.26)	52.05 (3.84)	0.04, 0.14, 0.23
Somatic complaints	54.10 (6.37)	53.67 (5.68)	52.61 (6.07)	0.07, 0.24, 0.18
Withdrawn	53.57 (4.77)	53.27 (5.68)	51.11 (1.57)	0.06, 0.69, 0.52
Sleep problems	52.57 (5.30)	51.67 (2.19)	52.83 (5.46)	0.22, −0.04, −0.27
Attention	53.00 (5.82)	51.53 (3.07)	50.72 (1.27)	0.32, 0.54, 0.35
Aggressive behavior	52.52 (5.26)	53.53 (7.11)	52.06 (4.07)	0.16, 0.10, 0.25
CBCL summary scales				
Internalizing problems	45.11 (13.17)	47.60 (9.88)	41.72 (10.12)	0.21, 0.29, 0.59
Externalizing problems	43.74 (12.25)	48.47 (10.26)	42.50 (10.22)	0.42, 0.11, 0.58
Total problems	43.26 (12.22)	46.67 (8.68)	40.11 (9.08)	0.32, 0.29, 0.74
SSRS scales	<i>n</i> = 14	<i>n</i> = 12	<i>n</i> = 17	
Cooperation	12.69 (2.34)	13.50 (4.40)	13.76 (2.77)	0.23, 0.42, 0.07
Assertion	15.61 (3.48)	15.91 (3.62)	16.52 (2.91)	0.08, 0.28, 0.18
Responsibility	12.15 (3.57)	12.50 (4.44)	14.00 (3.04)	0.08, 0.56, 0.39
Self-control	15.00 (3.91)	14.91 (4.16)	15.41 (2.45)	0.02, 0.12, 0.15
Standard score	105.23 (16.05)	106.50 (18.96)	112.35 (13.78)	0.07, 0.47, 0.35

M/S, moderate/severe group.

Medium effect sizes were found between the moderate/severe TBI and control group for the Withdrawn subscale. There were no significant group differences for the summary scores: internalizing $F(2,49) = 1.13, P = .33$, externalizing $F(2,49) = 1.31, P = .28$, and total score $F(2,49) = 1.67, P = .19$. Medium to large effect sizes were also detected between the moderate/severe and control group for each summary score. There were no significant differences for the proportion of children in the impaired range for the summary scores.

Parent ratings of social skills are shown in Table 4. There were no significant group differences on the subscales or summary scale, Wilks $\Delta = 0.91, F(10,72) = 0.35, P = .96$. There was a medium effect size between the mild TBI and the control group but otherwise the effect sizes between the groups were small. There were no group differences for the proportion of children in the impaired range for the Standard Score.

Predictors of Outcome

Hierarchical regression analysis was conducted with the SES at step 1 and lowest GCS (24 hours), family cohesion and parent mental health at step 2 (Table 5).

For VIQ and FSIQ, SES accounted for a significant amount of the variance, explaining 18.0% and 20.7%, respectively. For VIQ and FSIQ, the second step did not increase the predictive ability of the model significantly. There were no significant predictors of PIQ. For behavioral and social function, family function and parent mental health accounted for a significant amount of the variance.

DISCUSSION

The aim of this study was to examine the intellectual, behavioral, and social function after TBI sustained in very early

TABLE 5 Predictors of Intellectual, Behavioral, and Social Outcomes

Assessment	Step 1 Model R^2	β	Step 2 Model R^2	β	R^2 Total
VIQ	0.18**				
SES		.46**			
Lowered GCS			0.06	.15	0.24
Family function				-.03	
Parent mental health				.08	
PIQ	0.07				
SES		.26			
Lowered GCS			0.09	.25	0.16
Family function				-.19	
Parent mental health				.09	
FSIQ	0.22**				
SES		.46**			
Lowered GCS			0.03	.16	0.25
Family function				-.02	
Parent mental health				.07	
CBCL: internalizing	0.06				
SES		.24**			
Lowered GCS			0.37**	-.19	0.43
Family function				0.24	
Parent mental health				.68**	
CBCL: externalizing	0.03				
SES		.17*			
Lowered GCS			0.31*	-.28	0.34
Family function				.32	
Parent mental health				.55**	
CBCL: total score	0.01				
SES		.08			
Lowered GCS			0.39**	-.31	0.40
Family function				.39*	
Parent mental health				.66**	
SSRS: total score	0.09				
SES		.29			
Lowered GCS			0.24*	-.25	0.33
Family function				.50*	
Parent mental health				.42*	

** $P < .001$;

* $P < .05$.

childhood and to identify predictors of outcome. This was achieved by comparing children with TBI with an uninjured control group, equivalent in terms of age, gender, and SES.

Consistent with previous research,³⁹ there was an association between TBI severity and children's cognition; children with moderate/severe TBI performed below uninjured children, although they still achieved scores in the average range. In contrast, children with mild TBI performed similarly to controls. Surprisingly and contrary to previous findings,^{9,40} there were no group differences for processing speed. Although it is possible that TBI sustained before 3 years of age does not result in

processing speed deficits, it may be that the processing speed measure used (coding) was not sensitive to these impairments, that a composite measure rather than a single test should be used in future studies, that the time since injury has minimized differences, or that these skills are not sufficiently developed in the preschool years for the discrepancies from normal to be evident. Unfortunately, standardized intellectual assessment is limited in its sensitivity to TBI,⁴¹ and as such, often fails to capture the subtle but often more pervasive and debilitating functional impairments of children post-TBI. Although children with moderate or severe TBI may perform within the

average range on cognitive testing at a young age, this does not necessarily predict average cognitive abilities later on. This occurs, in part, because of the more limited demands placed on abstract or higher-level thinking skills at younger developmental levels. Research has shown that cognitive deficits after TBI sustained in very early childhood often do not emerge until much later in childhood with slow, steady declines over time.²⁰ These children will be followed up at 2-year intervals and will further contribute to our understanding of the impact of TBI in early childhood.

Contrary to predictions, there were no group differences for parent-rated behavior problems, although there were medium to large effect sizes between children with TBI and controls, suggesting possible differences with a larger sample size. There was a medium effect size for the mild TBI and controls for responsibility but otherwise there was also no indication that children with TBI had less developed social abilities than uninjured children. Behavior and social problems are consistently reported post-TBI in older children,^{17,23,27} and it is possible that problems may emerge in children as they mature.²¹ Other reasons for the null results include small sample size or the insensitivity of the measures to the specific behavioral and social outcomes of early TBI.

The substantive predictors of long-term intellectual, behavioral, and social function after early TBI were environmental factors, specifically SES, family function, and parental mental health,

consistent with previous research.^{28–30} For children who are younger at injury, it is likely that there are fewer outside influences on their development, and therefore more proximal factors, such as family and parental function, play a significant role in recovery. It is noteworthy that previous research indicates that certain psychosocial factors, such as low SES and increased parental stress, put young children at risk for sustaining a TBI.⁴² It appears from the findings that such factors also influence recovery post-TBI. Surprisingly, the injury factors in this case lowered GCS were not predictive of intellectual or behavioral function, possibly indicating the low reliability of measures such as GCS in very young children.³¹ These findings fit with previous research that injury severity had little predictive value of function levels in young children, instead SES is associated with intellectual function, and family environment is associated with behavioral function.²⁷

There are limitations to this study. First, measures of behavioral and social function were not available for all participants, and a larger sample size would have provided greater detection of group differences. Second, many studies investigating TBI highlight the value of an orthopedic control group to manage for the effect of injury^{28,29}; however, we selected uninjured children, matched for demographic factors, in keeping with the literature which argues that, in young children, environment (eg, family function and SES) is a critical risk factor for TBI, with

many injuries occurring in the context of disadvantaged families because of poor parental supervision.⁴³ Furthermore, socioeconomic factors were not related to injuries to parts of the body other than the head.⁴³ Similarly, recent research with children of preschool age reported significant differences between the families of children with TBI and children with orthopedic injuries in the areas of parental income and education,⁴⁴ important predictors of child function. Other limitations raised by other studies on this age group²² are also relevant, including the reliance on parent ratings for behavioral and social function and a lack of baseline data collected at time of injury.

CONCLUSIONS

The findings suggest that a moderate/severe TBI in early childhood is associated with reduced VIQ, PIQ and FSIQ scores in comparison with uninjured children or children with mild TBI. In contrast, a mild TBI appears to have limited effects on IQ. Results suggest that children with both mild and moderate/severe TBI are at risk for future behavior problems. The findings also highlight the additional risks associated with social disadvantage and cognitive and behavioral function.

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