Medical and Cognitive Outcome in Children with Traumatic Brain Injury

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ABSTRACT: ***Background:*** Head injury is an important cause of morbidity and mortality in pediatrics. Comprehensive studies on outcome are scarce despite significant clinical concern that multiple areas of functioning may be impaired following moderate to severe head injury. The literature suggests that sequelae include not only medical problems but also impairments in cognitive functioning. ***Methods:*** Aretrospective medical and psychology chart review of patients, age 1-18 years, admitted to the Children's Hospital of Eastern Ontario with moderate (Glasgow Coma Scale [GCS] 9-12) or severe head injury (GCS ≤ 8) from November 1, 1993 until December 31, 1998 was conducted. Correlations were performed between medical variables (i.e., GCS, Pediatric Risk of Mortality [PRISM] III score, duration of ICU and hospital stay) and measures of intelligence and memory functioning. ***Results:*** Eighty-three children age 1 to 18 were included. Seventy percent of the children were classified as having a severe head injury. There was a mortality rate of thirteen percent. Younger age at injury, lower GCS, and higher PRISM III scores predicted higher mortality. Medical complications were documented systematically. Forty-four patients underwent at least one cognitive assessment and 17 of these children had intelligence testing at three points in time: baseline (< four months), early recovery (five to 15 months) and follow-up (16 to 38 months). The mean intelligence and memory scores fell within the average range at the latest point in follow-up. For those children who underwent three serial assessments, the mean verbal and performance IQ fell within the low average range at baseline improving significantly to fall within the average range by early recovery. Continued improvements were apparent in verbal memory beyond early recovery, with the mean obtained at follow-up falling within 1 SD of the normative mean. Despite the return to normal ranges for the group means the proportion of scores falling below 1.5 standard deviations from the mean was greater than population norms for verbal IQ, performance IQ and verbal memory. Lower GCS scores and longer duration of stay in ICU or hospital were predictive of lower nonverbal intelligence. Lower GCS was also predictive of lower visual memory scores. ***Conclusions:*** This study describes a population of Canadian children who suffered moderate or severe traumatic brain injury. Initial GCS was the best predictor of mortality and cognitive outcome. These children demonstrated a temporal improvement in intelligence and memory functioning, with their mean performance on these cognitive measures falling within the average range at 16 to 38 months postinjury, although there was considerable variability in the outcomes between individuals.

RÉSUMÉ: Évolution médicale et cognitive chez les enfants ayant subi une lésion cérébrale traumatique modérée ou sévère. ***Introduction***: Les traumatismes crâniens sont une cause importante de morbidité et de mortalité en pédiatrie. Bien que l'évolution clinique de ces cas suscite l'inquiétude quant aux répercussions sur de multiples domaines du fonctionnement, il existe peu d'études exhaustives sur le sujet. La littérature suggère que les séquelles sont non seulement d'ordre médical mais aussi d'ordre cognitif. ***Méthodes***: Nous avons révisé de façon rétrospective les données médicales et psychologiques contenues dans les dossiers de patients âgés de 1 à 18 ans, admis au Children's Hospital of Eastern Ontario avec un traumatisme crânien modéré (Glasgow Coma Scale [GCS] 9 à 12) ou sévère (GCS £ 8) du 1e novembre 1993 au 31 décembre 1998. Des études de corrélation entre les variables médicales (GCS, Pediatric Risk of Mortality [PRISM] III, durée d'hospitalisation et de séjour à l'unité de soins intensifs) et des mesures de fonctionnement intellectuel et mnésique ont été effectuées. ***Résultats***: L'étude a porté sur 83 enfants, âgés de 1 à 18 ans, dont 70% avaient subi un traumatisme crânien considéré comme sévère. Le taux de mortalité était de 13%. Le jeune âge au moment du traumatisme, un GCS plus bas et un score PRISM III plus élevé étaient associés à une plus grande mortalité. Les complications médicales étaient rapportées systématiquement. Quarante-quatre patients ont subi au moins une évaluation cognitive et 17 de ces enfants ont eu un test d'intelligence à trois reprises pendant le suivi, soit moins de quatre mois, entre 5 et 15 mois et plus tardivement, soit entre 16 et 38 mois après le traumatisme. Les scores moyens aux tests d'intelligence et de mémoire étaient dans la moyenne à la dernière évaluation. Chez les enfants qui ont subi trois évaluations successives, le QI verbal et le QI fonctionnel qui étaient dans la moyenne basse initialement, se sont améliorés de façon importante par la suite. La mémoire verbale a continué de s'améliorer tardivement, la moyenne obtenue au suivi tardif étant à un écart type de la moyenne normative. Bien que la moyenne soit revenue dans l'écart normal, la proportion des scores plus bas qu'à 1.5 écarts type de la moyenne était supérieure à celle de la population générale pour le QI verbal, le QI fonctionnel et la mémoire verbale. Un GCS plus bas, un séjour plus long à l'unité de soins intensifs ou à l'hôpital étaient prédictifs d'une intelligence non verbale plus basse. Un GCS plus bas était également prédictif de scores plus bas à l'évaluation de la mémoire visuelle. ***Conclusions***: Cette étude décrit un échantillon d'enfants canadiens victimes d'un traumatisme crânien modéré ou sévère. Le GCS initial était l'élément qui prédisait le mieux la mortalité et l'évolution cognitive. On a observé chez ces enfants une amélioration dans le fonctionnement intellectuel et mnésique avec le temps. Leur performance dans ces domaines était dans l'écart moyen à l'évaluation faite entre 16 et 38 mois après le traumatisme. Il y avait cependant beaucoup de variabilité entre les individus dans la récupération.

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Trauma is the most common cause of death in North America for individuals between the ages of one and 24 years.[1] Furthermore, traumatic brain injury (TBI) is the leading cause of trauma admission in children, and is the cause of 70% of the deaths due to trauma.[2] Injuries are more frequent in males, and are most commonly due to motor vehicle accidents, bicycle accidents, falls, sports injuries and child abuse.[3-8] Clearly TBI in children represents a significant cause of mortality and morbidity, and thus, is directly responsible for a large expenditure of health care resources.

Brain injury due to trauma has the potential to cause physical, cognitive and psychological deficits[9] but there is a need to develop better methods of predicting outcome. Historically medical parameters including duration of coma, post-traumatic amnesia, and type of injury have been used to predict the outcome of children with TBI.[10-13] The duration of coma and post-traumatic amnesia have limited value as predictors of outcome, due to liberal use of analgesics and sedatives in the intensive care unit (ICU). The medical predictors used in the current study include the Glasgow Coma Scale (GCS), duration of ICU and hospital stay, and the Pediatric Risk of Mortality (PRISM III) score,[14] a physiologic-based risk score.

Attempts to describe cognitive and psychological outcome with greater precision have led to the use of tests of intelligence in survivors of pediatric TBI. Despite methodological differences across studies, gradual improvements in intelligence quotients (IQ) are commonly reported in survivors of moderate and severe head injury, with greater gains apparent on measures of nonverbal intelligence.[10,15,16] Varied opinions have been offered regarding the clinical significance of these improvements and the utility of IQ as an indicator of overall functioning in this population.

There are fewer studies examining long-term recovery of memory functioning in children with moderate or severe head injury. Clarifying the severity, scope, persistence and medical predictors of memory dysfunction in this population is critically important, as these deficits can be expected to have an adverse effect on their educational progress and learning.[17-19] The Wide Range Assessment of Memory and Learning (WRAML),[20] which is normed for children from the age of 5 years, 0 months to 17 years, 11 months and tests immediate recall was used in this study. To date, there are no published reports of outcome in memory functioning for head injured children using the WRAML.

This study outlines the epidemiological parameters of a population of children with moderate and severe head injury seen at a Canadian tertiary care pediatric trauma centre over a five-year period. The purpose of this investigation was to find medical prognosticators for mortality and cognitive functioning over three years following injury. The current study is unique in the use of the WRAML, a psychometric instrument that includes measures of both verbal and visual memory, and the PRISM III score, a novel prognosticator.

METHODS

Population

The Children's Hospital of Eastern Ontario is a tertiary care pediatric trauma centre serving approximately 1.5 million people in eastern Ontario and western Quebec. This study represents a retrospective review of all patients, ages one year to 18 years, presenting with a moderate or severe head injury between November 1, 1993 and December 31, 1998. An inclusion age greater than one year was chosen in this study in an effort to assess the impact of age on outcome while not including a large number of inflicted head injury cases (i.e., abuse victims). Only two children had inflicted head injury in this study. Standard care for pediatric TBI in this centre at the time of this study included resuscitation in the Emergency Department, computed tomography (CT) scan of the head, admission to the Pediatric ICU and management with supportive care. Patients with severe TBI were managed with intracranial pressure lowering therapies where indicated. These therapies consisted of fluid resuscitation; intubation and mechanical ventilation; sedation and analgesia; osmotherapy; and barbiturates. Cerebral perfusion pressure was supported with boluses of intravenous fluids and ionotropes. Surgical intervention was used when indicated.

Procedures

This study was approved by the institutional ethics committee. We searched health records and identified all children admitted with head injury over the study period. The charts were examined and children with initial GCS≤12, were selected for review. The GCS was determined by an emergency physician, neurosurgeon or other trauma team member at our hospital or an outlying community hospital. Children with a GCS ≤8 at presentation were considered to have had a severe head injury and those with a GCS from 9 to 12 were considered to have had a moderate head injury. Death records in the emergency department were hand searched to find children who had died from head injury prior to admission. Children identified as having a pre-existing psychiatric or neurological disorder (e.g., epilepsy, cerebral palsy) or prematurity (<36 weeks gestational age) were excluded.

Procedures: Medical Chart Review

The medical charts were reviewed for the following demographic data: age at time of injury, date of injury, transfer from a peripheral facility, mechanism of injury and initial GCS. The findings of the first CT scan of the head were also collected. Results from neuro-imaging other than the initial CT were not included in this study due to variability in timing and type of imaging used.

In-hospital factors recorded included: intracranial pressure, neurosurgical intervention required, days of ventilation, and length of stay in pediatric ICU and hospital. The PRISM III score was calculated as described by Pollack et al[14] for the first 24 hours in the ICU as an indicator of severity of illness. The type and number of complications that occurred during admission and following discharge were recorded from the physician's progress notes or consultant's notes.

Procedures: Psychology Chart Review

The psychology files were reviewed to obtain cognitive data on all children identified during the health records search. The timing of the assessments was grouped into three phases: baseline (six days to four months post-injury), early recovery (five months to 15 months post-injury) and follow-up (16 months to 38 months post-injury). The grouping of assessments

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was based on patterns of recovery observed in our setting and they correspond to intervals used in other investigations of TBI in children.[21,22] A subset of patients had serial cognitive assessments. The IQs were obtained using the Wechsler Scales[23-26] appropriate for the age of the child at the time of testing. Visual and verbal memory indexes were obtained using the WRAML.[20] The indexes from this test are composite scores derived from the child's performance across a number of subtests. Only one of the visual memory subtests from the WRAML places demands upon motor skills and spatial organization. Thus, the recovery of visual memory functioning is less likely to be confounded with that of motor and spatial organization deficits when using the WRAML.

Statistical Analyses

Descriptive statistics were used to summarize the demographic variables. Means and standard deviations were also generated for IQ and memory for the group of children who were assessed at least once during recovery. Pearson Product Moment Correlations were used to examine relationships between the medical variables and cognitive outcome for the entire group of patients seen at follow-up. All tests were two-tailed with statistical significance considered as an alpha ≤0.05. Repeated measures analyses and paired t-tests were used to examine changes over time in IQ and memory for a subset of patients with more than one cognitive assessment. Given the well-recognized variability in outcome following moderate and severe head injury, the use of a repeated measures design allows for greater control over individual variability.[27]

Results

Eighty-five children were identified as eligible for this study. Two children were excluded: one due to a significant pre-existing debilitating psychiatric disorder, and one due to prematurity (30 weeks gestation). Thus 83 were included in the analyses. Fifty-eight (70%) of the children were classified as having had a severe head injury. Eleven (13%) children did not survive, leaving 72 children available for follow-up. Of these, 44 (61%) had one, two or three cognitive assessments and 17 of those had serial evaluations at three points in time. Twenty-eight (39%) children did not receive complete cognitive testing. Two of these children were under the age of three years and therefore too young to complete the Wechsler Scales. Four children were transferred to another hospital, one could not be offered testing in his native language, one was over 18 years of age by discharge, and one was not testable due to a tracheostomy. Nineteen were not referred for assessment or were lost to follow-up for unknown reasons. Comparisons made between the 44 children who had at least one assessment and the 28 who had no psychology follow-up revealed that the two groups did not differ significantly with respect to GCS, PRISM III score, age at injury, or duration of hospital stay. A significant difference ($t(64)=2.05$, $p=0.04$) was obtained for duration of ICU stay with those without psychology follow-up staying on average three days less in ICU.

Medical parameters

Medical parameters and the presenting characteristics for the whole group (n = 83), those who underwent three serial cognitive assessments (n = 17), and those who did not survive (n = 11), are presented in Table 1. Motor vehicle accidents accounted for 65% of the injuries with falls (7%), bicycle accidents (6%) and abuse (5%) being important mechanisms as well. Other injuries contributing to the total included: tobogganing (n = 2), down hill skiing fall (n = 2), struck by object (n = 2), all terrain vehicle passenger (n = 2), snowmobile accident (n = 1), fall from slide (n = 1), being pushed (n = 1), kicked by horse (n = 1), gunshot wound (n = 1), and jet ski accident (n = 1).

Table 1: Presenting features and in hospital variables of 83 children with moderate or severe traumatic brain injury.

Parameter	All children (n=83)	Children with 3 serial cognitive assessments (n=17)	Children who died (n=11)
Number of males (%)	46 (55)	10 (59)	7 (64)
Age at time of injury mean±s.d., (range)	9.7±4.3 (1-17.8)	9.7±4.3 (3.9-16.4)	7.4±5.6 (1-14.9)
Number of accidents May-October (%)	46 (55)	11 (55)	7 (64)
Initial GCS mean±s.d., (range)	6.9±2.8 (3-12)	6.7±2.5 (3-11)	3.3±0.7 (3-5)
Number of children with a GCS ≤8 (%)	58 (70)	14 (82)	11 (100)
Number of children with injury outside CNS (%)	49 (59)	10 (59)	8 (73)
PRISM III score mean±s.d., (range)	9.9±8.5 (0-47)	8.9±3.8 (4-17)	27.0±10.8 (7-47)
Number of children having neurosurgery (%)	20 (25)	6 (35)	0 (0)
Duration of ICU admission days mean±s.d., (range)	5.1±6.0 (0-30)	7.4±7.2 (1-23)	2.3±2.7 (0-9)
Duration of hospital stay days mean±s.d., (range)	23.8±34.9 (0-180)	32.9±32.4 (6-120)	2.3±2.7 (0-9)
Number of children with sustained ICP elevation over number with ICP monitoring*	9/14	2/5	3/4
Number of complications per child mean±s.d., (range)	2.4±2.5 (0-12)	3.8±3.5 (0-12)	0.9±1.0 (0-3)

* Sustained ICPelevation is defined as >20mmHg for >1 day
ICP=intracranial pressure

Mortality

There were 11 deaths (13% of the entire group; 20% of the severely head injured group) all of which occurred during the admission for head injury. Most deaths occurred in the first 48 hours, however, one child died at nine days. All deaths, except for two children with cardiopulmonary arrest in the ER, were a result of marked cerebral edema, which was apparent on the initial CT scan, leading to brain death. No child died in the

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Table 2: Medical complications in 83 children with moderate or severe traumatic brain injury.

Type of Complication	Number of children experiencing each complication during hospital admission	Number of children experiencing each complication following discharge
Injury specific neurological deficit*	24	11
Nosocomial infection	13	n/a
Seizure (s)	12	3
Poor gastrointestinal motility	8	0
Behavioural and mental status changes	7	19
Headache	6	15
Occipital pressure ulcers	6	2
Anemia	6	0
Diabetes insipidus	5	0
Hypotension	4	0
Fever of unknown origin	4	0
SIADH	2	0
Hydrocephalus (requiring shunt)	2	2
Cranial neuropathy (6th)	2	1
Non-specific physical symptoms	1	6

SIADH = syndrome of inappropriate antidiuretic hormone release
*An injury-specific neurological deficit was any physical finding noted in the physician notes that was attributed directly to the head injury. These consisted primarily of focal motor deficits, but also included a/dysphasia, visual and hearing impairment.

Table 3: Intelligence and memory indexes for children with at least one assessment following moderate or severe head injury (N = 44). Data are expressed as mean ± S.D.

	Baseline (<4 months)	Early Recovery (5-15 months)	Follow-Up (16-38 months)
INTELLIGENCE			
Verbal IQ	84.1 ±15.8 (n=37)	88.4 ±14.9 (n=35)	90.9 ±14.3 (n=25)
Performance IQ	82.8 ±18.2 (n=39)	90.7 ±22.8 (n=35)	95.6 ±20.2 (n=25)
Full Scale IQ	81.1 ±15.8 (n=36)	88.0 ±18.2 (n=35)	91.9 ±16.8 (n=25)
MEMORY			
Verbal Index	80.9 ±18.6 (n=22)	83.1 ±14.6 (n=31)	87.1 ±19.1 (n=22)
Visual Index	88.7 ±15.1 (n=24)	91.1 ±19.3 (n=30)	93.1 ±15.0 (n=22)

The variability in sample size especially at baseline reflects conditions (e.g. aphasia, hemiparesis, etc.) that interfered with the child's ability to complete tests.

follow-up period of other causes. As with the total sample, most of the children who did not survive had sustained a head injury from a motor vehicle collision. Additional causes of the fatal injury included: abuse (n = 1), gunshot wound (n = 1) and bicycle accident without a helmet (n = 1). Complications were noted in seven of these 11 children including diabetes insipidus (n = 3), seizures (n = 2), hypotension requiring ionotropes (n = 2) and disseminated intravascular coagulopathy (n = 1). The mean GCS for children who died was 3.3±0.7, whereas that of those who survived was 7.5±2.6. This difference was statistically significant ($F(1, 81)=29.38$, $p<0.001$). The mean PRISM III score for children who died was 27.0±10.8 which was significantly higher ($F(1, 75)=89.50$, $p<0.001$) than that of those who survived 7.6±4.8. The children who died were on average three years younger at the time of injury than those who survived ($F = 4.00(1, 81)$, $p = 0.05$).

Complications

Complications during the hospital admission were documented in 48 (58%) of children and complications post-discharge were noted in 35 (42%). Information regarding complications post discharge was not available on nine children. Only 13 (16%) children did not have any documented complications in either period. The types of complications are listed in Table 2.

Cognitive Outcome

A description of the global level of functioning was obtained by generating means for verbal, performance and full scale IQ, as well as verbal and visual memory for the group of 44 patients with at least one cognitive assessment. These means are presented in Table 3. Group means for the verbal, performance, and full scale IQ obtained during the baseline assessment (< four months postinjury) fell in the low average range. The group means for verbal and full scale IQ obtained during the assessments conducted in early recovery (five to 15 months post-injury) also fell within the low average range, whereas the mean performance IQ fell just within the average range. At follow-up (16 to 38 months postinjury), the means for all three measures of intelligence fell just within the average range. The verbal memory means were consistently lower than the visual memory means at all three points in recovery. The means for verbal memory obtained at baseline and early recovery fell more than one standard deviation below the level expected from the normative data for this test. All other means fell within normal limits, but there was considerable variability.

A one way analysis of variance demonstrated no significant differences between IQ and memory indexes for those whose injury affected primarily the right or left hemisphere. These results must be interpreted with caution as those individuals with aphasia secondary to left hemisphere injury were too compromised to participate in all three assessments.

Correlations were used to examine relationships between the medical variables and cognitive outcome for all of the 44 patients with at least one cognitive assessment. The medical variables included: age at time of injury, GCS, duration of ICU stay, duration of hospitalization, and PRISM III scores. Age at injury was not significantly correlated with any of the cognitive measures of outcome, but young age appeared to correlate with worse scores on visual memory ($p=0.07$), although this did not

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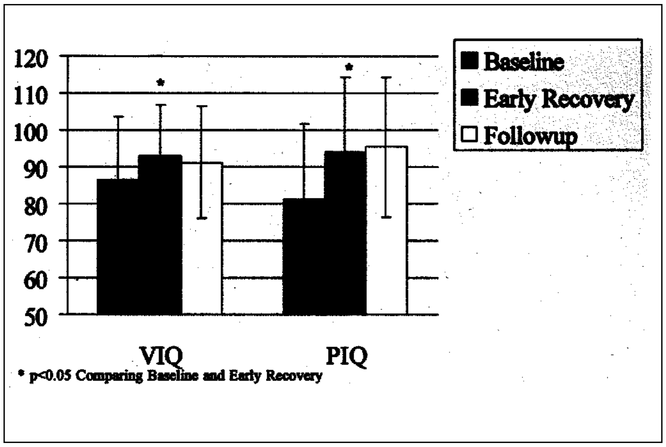

Figure 1: *Verbal and performance IQ for the subset of children (n=17) who underwent three serial cognitive assessments. Data are expressed as mean ± S.D.*

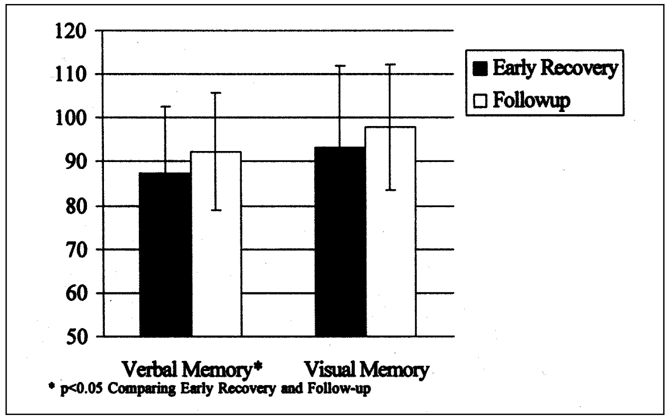

Figure 2: *Verbal and visual memory for a subset of children (n=12) who underwent two assessments. Data are expressed as mean ± S.D.*

reach statistical significance. The GCS was positively correlated with performance IQ (r=0.63, p<0.004) and visual memory (r=0.48, p<0.04). The correlation between GCS and verbal IQ approached statistical significance (p=0.07), as did that with verbal memory (p=0.06). Duration of ICU stay and duration of hospital stay were both negatively correlated only with performance IQ (r=-0.58, p<0.01 for both). The correlation between PRISM III score and verbal memory approached statistical significance (p=0.07).

Given the variability in individual outcome that is characteristic of the head injured population, repeated measures analyses were conducted on the intelligence data from a subgroup of 17 children (39%) who had completed three serial assessments. The presenting features and medical variables for this subset of children were similar to those of the whole group (Table 1). The means for verbal and performance IQ are presented in Figure 1. A significant main effect of time was obtained (F(4,13) =3.72, p = 0.031). Follow-up univariate tests confirmed that the effect of time was apparent for both measures of intelligence (verbal IQ: (F(2, 32) = 3.92, p =.030), performance IQ: (F(2, 32) = 11.46, p = 0.000)). *A priori* repeated contrasts showed that the significant change occurred between baseline and early recovery for both measures of intelligence (verbal IQ: (F(1, 16)=7.21, p=.016), performance IQ: (F(1, 16)= 16.29, p=0.001)). The change between early recovery and follow-up was not significant for either measure of intelligence.

Two serial assessments of memory functioning at early recovery and follow-up were also available for 12 children (ten severe and two moderate head injury). The means for verbal and visual memory are represented in Figure 2. Paired t-tests indicated that the difference between the verbal memory means was statistically significant (t(1, 11) = -2.44, p = 0.03), and the direction of the difference was consistent with an improvement in memory functioning from early recovery to follow-up. The difference between the visual memory means was not significant (t(1, 11) = -1.26, p = 0.23). All of the memory means were within one standard deviation of the mean for the normative population.

Discussion

We found good recovery of cognitive functioning in children with moderate to severe head injury, with mean scores on all measures of intelligence and memory functioning falling within the average range when assessed at between 16 and 38 months following head injury. It is important to note, however, that the range of scores was large with a significant proportion of children demonstrating low scores. Verbal memory means fell more than one standard deviation below the normative mean when assessed within 15 months following the head injury, before returning to within the average range by the later follow-up. This finding is of particular importance since the period of early recovery corresponds to the time at which most of these children would be returning to school.

Lower initial GCS scores were associated with lower nonverbal intelligence and poorer performance on measures of visual memory. Longer duration of ICU stay and hospital stay were also predictive of lower nonverbal intelligence.

The mortality was 20% in the children with severe head injury in our series. In a recent review of studies conducted in North American centres, mortality rates amongst the severely head injured ranged from 6%-59%.[5]

Medical complications of head injury, such as seizures and nosocomial infections were common in our series. Previous studies have reported similar high rates of medical complications following moderate and severe head injury.[28-30] Symptoms consistent with post-concussion syndrome[31] such as behavioural changes, headache, and nonspecific physical symptoms increased three-fold following discharge from hospital in our series.

Although the duration of follow-up in the current study was longer than in other studies[10,15,16] the findings for intelligence are consistent with these studies, with group means generally falling within the average range at follow-up. However, reliance solely on normative data may underestimate the incidence and severity of intellectual impairment in this population. In studies that used matched controls with no head injury, children had a higher

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percentage of cognitive impairment following head injury.[22,32]

Results of the current study revealed a significant improvement in verbal memory from early recovery to follow-up in the children who underwent serial assessments. The verbal memory mean obtained at follow-up fell just within normal limits, as did the visual memory at all three points in recovery. These results suggest a better outcome for both verbal and visual memory than previously reported in the literature.

The discrepancy between the findings for memory functioning from our study and those of others is likely attributable to differences in the measures used. The WRAML used in our study tests immediate recall for both verbal and visual memory. Previous studies have demonstrated persistent impairment in delayed recall using tests of both verbal and visual-spatial memory in children with severe head injury.[11,16,33-35] Further investigations are needed, using a comprehensive measure of verbal and visual memory that includes age norms for both immediate and delayed recall.

Children who died were significantly younger than those who survived in our study. Age at injury is known to influence survival in children with head injury with higher fatality rates demonstrated for the younger child.[3,6,7] The significant effect of age at injury on mortality was noted, in our study, even though we excluded infants less than one year of age. Many children who sustain a head injury before one year of age are victims of abuse and this etiology is associated with greater morbidity and mortality.[36-38] In order to minimize the influence of abuse, we excluded children who sustained their injury in the first year of life.

The utility of the GCS to predict severity and outcome of head injury is limited by several factors. In a survey conducted by Marion et al,[39] marked discrepancies in application of the initial GCS were noted between pediatric hospitals and between different health care personnel. Despite these limitations, the GCS has consistently been shown to be a useful predictor of outcome following head injury.[7,8,36] The current study demonstrated an inverse relation between the initial GCS scores and mortality. This finding is consistent with reports in the literature.[36] Investigators have generally reported an association between head-injury severity and intelligence scores, most notably with performance IQ.[12] In the current study, the measure of head injury severity (GCS) was positively correlated with performance IQ and visual memory at 16-38 months post-injury. This suggests that even two to three years after injury, those children who suffered a more severe injury, as measured by the GCS, may experience continued difficulty with nonverbal problem solving and memory.

The PRISM III score was used in this study as another index of severity. This score is primarily a physiologic score and it takes into account many factors both directly related to the head injury and other physiological abnormalities that can impact on the dynamics of head injury in the first 24 hours.[14] In the current study, the PRISM III scores of children who died were substantially higher than those of survivors. Higher PRISM III scores appeared to correlate with lower verbal memory scores although the correlation was not statistically significant. Using the predecessor of this score, the PRISM, Thakkar et al[36] reported a significant association between higher scores and “bad outcome”, defined as mortality or partial or total dependency following severe head injury in children. The use of the PRISM III and other physiological scores warrants further examination in children with TBI.

We were concerned about the number of children with moderate or severe head injury that were not seen in follow-up in our review. Other studies of head injured children have also been hampered by a high attrition rate.[6,32,40] Despite this, a comparison of the groups with and without psychology follow-up in our study does not demonstrate substantial differences on many demographic and injury related factors.

The impact of the cognitive deficits on the daily functioning of the child and their quality of life was beyond the scope of this study. As well, the perceived suffering of the patients and families should be examined in future studies.

Finally, examination of the quality of acute care and its impact on mortality and cognitive outcome was beyond the scope of this study. Our rate of intracranial pressure monitoring of children with severe head injury appears to be low (14 of 58 children, Table 1) and we speculate that a higher rate of intracranial pressure monitoring might have improved mortality and cognitive outcome. We currently recommend intracranial pressure monitoring to direct therapy in children and adolescents with GCS≤8 and an abnormal CT scan at risk for development of cerebral edema. These recommendations are from Canadian consensus-based guidelines made following a systematic review of the literature (unpublished). Recently published American guidelines make similar recommendations.[41] We believe that use of these guidelines will improve the outcome in children and adolescents with severe head injury.

Researchers studying head injury in children a decade ago commented on the high variability in individual outcome following TBI in children.[27] Difficulties remain today in predicting outcome, which may be due in part to the dynamic nature of the pediatric nervous system, but perhaps also to the limitations in our ability to quantify the complexity of the injury and to measure its full impact on neurodevelopment. Ideally the future study of head injury in children will bring about a formulation of patient injury parameters that adequately predicts a child’s outcome in multiple spheres, such that care providers and parents can make more informed decisions and that new therapies can be adequately appraised.

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