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Neuropsychological Functioning of Children and Youth with Acquired Brain Injury 2 Years after Onset

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Abstract

Background: Neurocognitive deficits following pediatric acquired brain injury (ABI) often remain under reported, whereas these sequalae impact several domains of activities and participation.

Objective: To screen neurocognitive consequences of pediatric ABI in a hospital-based cohort using both a professional and parent reported screening tool.

Methods: Follow-up study including children with a hospital-based diagnosis, aged 4-20 years at onset of ABI, using the Processing Speed and Attention subtests of the Amsterdamse Neuropsychological Tasks (ANT) and the parent reported Brain Injury Alert (BIA). Age, type and severity of injury were used in analysis as associated factors.

Results: 103 children, aged 4 up to 20 years (median 13y) at onset of ABI, were assessed 2 years later. 89 (86%) on injuries were classified as mild and 80 (78%) had a traumatic cause (TBI). The study cohort responded more accurate (accuracy 29.4-30.4%, >1 SD) and slow (inhibition speed 25.5-38.2%, >1 SD) on the ANT tasks compared to the norm group without neurocognitive deficits. One or more cognitive problems were reported by 62 (65%) of the parents, 1 or more social emotional problems by 66 (69%) and 1 or more cognitive and social emotional problem by 70 (77%). Type (NTBI) and severity (moderate/severe) of injury were associated with worse neurocognitive outcome in both professional (ANT) and parent reported (BIA) outcome, whereas age (younger age group) was only associated with parent (BIA) outcome.

Conclusion: Neurocognitive problems were found in this hospital-based cohort of children with ABI, especially in the older age and NTBI group, with parents reporting strikingly more problems than professionals.

Keywords: Traumatic brain injury; Non traumatic brain injury; Cognitive functioning; Emotional functioning; Social functioning; Behaviour; Young adults

Introduction

Acquired Brain Injury (ABI) in children young adults (25 years), refers to any damage to the brain that occurs after birth and may result from events with an external cause (Traumatic Brain Injury, TBI) or internal cause (Non-Traumatic Brain Injury, NTBI) such as brain tumor, stroke or infections such as meningitis or encephalitis [1,2]. With ABI, depending on its nature and severity, multiple neural systems may be involved, resulting in a large variety in combinations of potential neurocognitive and emotional-behavioral consequences [3,4]. The course of outcome after ABI is highly variable, ranging from full recovery, persisting and severe impairment, absence of impairment initially, with emerging problems over time to early slowed development, with catch-up over time [5,6].

Patients with ABI and caregivers experience neurocognitive limitations as major, chronic and most disabling problems. The most common functional neurocognitive outcomes following brain injury reported, in mild as well as moderate and severe ABI, are impairments of attention, memory, processing speed and executive dysfunction, reciprocal influencing in problems in problemes fatigue or sleep rhytm [7-15]. These acquired neurocognitive consequences adversely affect activities of daily living and social and societal participation [16].

Injury characteristics severity (moderate/severe>mild) and type (NTBI>TBI), age at onset (younger>older), environmental factors and interventions have been identified as being associated with negative and long-term neurocognitive impairments [17-19]. The developmental stage of the brain at onset of the injury is also crucial: growth, maturation and development of the brain interact with injury parameters and impact on acquisition and modification of knowledge, competences and skills and executive functions (e.g. in transitions to higher levels of education, work, social intimacy or living independently) [20-23]. This cumulative phenomenon, the interaction between growth, maturation and ABI, is called 'growing into deficit' [20,24,25].

However, literature on neurocognitive outcomes in children and young adults with ABI shows inconsistent results, due to differences in definitions and methodology, especially regarding classification, variety in age at inclusion, age range, time since onset of injury, follow-uptime [26-29]. Moreover, the vast majority of research was focussed on TBI. Although it is suggested that the consequences of NTBI are often similar to those of TBI, due to differences in their causes and nature the outcome after a TBI cannot be extrapolated to the various aetiologies of NTBI [25].

The importance of screening and monitoring consequences of pediatric ABI are broadly supported, with a longer follow up than 6-12 months after onset, to enable interventions for the child and family and school support [8,19]. In the assessment of neurocognitive consequensces of pediatric ABI it is recommended to merge different

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perspectives to get a more complete and ecological valid impression of the Childs' neurocognitive functioning and activities and participation [26], idealy these assessments should be based on different perspectives: i.e., child, parents and professional [27-30].

Therefore the aim of our study was to assess neurocognitive problems in a hospital-based cohort of children with ABI, 2 years after onset, using a parent and professional reported screening tool.

Our 1st hypothesis was, that type (NTBI>TBI) and severity (moderate/severe>mild) of injury and age group (young>old) would be associated with worse results on the neuropsychological screening and the the parent's report. Our 2nd hypothesis was that parents report more neurocognitive problems than professionals.

Methods

Design and setting

This study on neurocognitive consequences was part of a larger cross-sectional two year follow-up study on outcome of ABI in children and youth aged 5-23 years living in the south-western part of the Netherlands [31-33]. A stratified sample was drawn from a multi-centre incidence cohort of 1892 patients with a diagnosis of ABI, year of onset 2008 or 2009, from large tertiary care hospitals in Rotterdam (Erasmus University Medical Centre, including Sophia Children's Hospital) and The Hague (Haga Hospital, including the Juliana Children's Hospital and Medical Centre Haaglanden). The sample was stratified for year of onset (2008; 2009), severity of injury (mild; moderate; severe) and age at onset (3-12 years; 13-21 years).

The classification of TBI was done during hospital admission, using The Glasgow Coma Scale (GCS). The GCS is a neurological scale which aims to give a reliable and objective way of recording the conscious state of a person for initial as well as subsequent assessment. A patient is assessed against the criteria of the 3 scales: Eye Response, Motor Response and Verbal Response, with the resulting points give a patient score between 3 (indicating deep unconsciousness) and 15. TBI was considered mild if the GCS was 13-15, moderate if the GCS was 9-12 or severe if the GCS was <9 [34]. The modified Ranking Scale (mRS) is a commonly used scale for measuring the degree of disability or dependence in the daily activities of people who have suffered a stroke or other causes of neurological disability (NTBI). The scale runs from 0-6, running from perfect health without symptoms to death. The severity of NTBI was determined at the time of discharge of the hospital: Mild injury (no limitations; mRS 0,1), moderate injury (mild motor impairments and/or mild problems with learning; mRS 2,3) and severe injury (severe motor impairments and/or severe problems with learning; mRS 4,5) [35].

Patients were first selected by age and subsequently a search in the patient files was performed using diagnosis codes and search terms related to ABI. Diagnosis codes are derived from the International Statistical Classification of Diseases and Related Health Problems (ICD-codes). The computer-based search strategy included the following terms: minor head injury, traumatic brain injury, concussion, skull/brain trauma, neurological trauma, epilepsy, brain tumour, stroke, infections (meningitis/encephalitis), post anoxia, ADEM (acute disseminated encephalo myelitis), MS (multiple sclerosis) or acute CNS (central nervous system) demyelinating disease and hypoxia-ischemia were labelled as NTBI. Participants were excluded if they were diagnosed with trauma capitis (minor head injury without brain symptoms).

The two year follow-up study was approved by the Medical Ethical Committee (METC) of the Erasmus University Medical Centre Rotterdam (METC-2009-440). All parents and patients, as required by law from 18 years, participating in the follow-up assessment gave written informed consent.

Participants

For the lager study patients were selected from the registries of the participating hospitals using the clinical diagnosis as mentioned above. Inclusion criteria for the follow-up study were: age at onset ABI (3-21 years) and parents' ability to understand and complete questionnaires in Dutch. Of all patients participating in the larger study, the age of onset, gender, type and severity were extracted from the medical records.

To select patients for the follow-up study the total group of participants was categorized by age (up to 14 years>older than 14 years), type of injury (TBI and NTBI) and severity of injury (mild-moderate/severe) (Figure 1) .

The patients in the stratified samples for 2008 and 2009 were invited, about 2 years (Figure 1) after onset of ABI, to participate in the study by sending the Patient Information Letter. Non responders were followed up after 2 weeks by a telephone call. After receiving the Patient Informed Consent an 'appointment assessment' was made for a consecutive neurological (60 min) and neuropsychological (60 min) screening. All neuropsychological testing was done according to the standard procedures for assessment. Parents also filled in the Dutch version of the BIA, a questionnaire about the cognitive and social emotional functioning of the child and give this to the neuropsychologist or returned it by post. Data were collected by two neuropsychologists under supervision of the principal investigator. Participants received a written report with results of the screening, integrated by the medical specialist. Participants were invited for a consult at the rehabilitation medical specialist if indicated by scores on medical and neuropsychological measures.

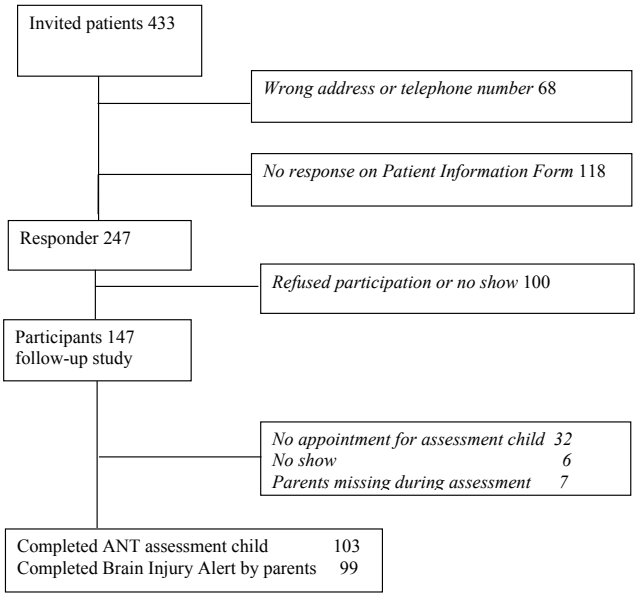

Figure 1: Flow chart recruitment.

Instruments

Neuropsychological measures

Cognitive functioning was measured with the Amsterdamse Neuropsychologische Tasks (ANT) program [36-38]. The ANT was found to be suitable to detect neuropsychological dysfunctions in patients with leukemia after chemotherapy and psychiatric conditions commonly associated with attention deficit disorders and behavior problems [39-42]. The ANT program evaluates various aspects of cognitive functioning. For this study the following two neuropsychological tests from the ANT were administered: Baseline Speed (BS) (test of attention) and Shifting Attentional Set – Visual (SSV) (test of response inhibition and flexibility), in order to screen most often occurring neuropsychological consequences of pediatric ABI [3,14,18,26,27].

1. Baseline Speed (BS), a test of attention (alertness) and speed (reaction time) involving minimal cognitive effort. The participant is required to press a mouse-key as quickly as possible when a fixation cross in the center of the computer screen changes into a white square (n=32 trials for left and right hand each). Main outcome parameters are the mean reaction time (in milli seconds, ms) of the dominant hand and the within-subject standard deviation of the reaction time (i.e., response speed stability) [43,44].

2. Shifting Attentional Set - Visual (SSV), a test of attentional flexibility, an important aspect of executive functioning. A colored square moves randomly to the right or to the left on a horizontal bar that is permanently present on the computer screen. The task consists of three parts. Depending on the color of the square, compatible responses (copying, part 1), or incompatible responses (mirroring, part 2) are required, by pressing the mouse-key on the same side as the direction of movement of the square (part 1), or on the side opposite to the direction of movement of the square (part 2). In these parts, the stimulus–response (SR) compatibility is fixed (either spatially compatible or incompatible). The incompatible condition requires inhibition of pre-potent responses. During part 3, the color of the moving square varies randomly, requiring attentional flexibility by continuously having to adjust response type (compatible/incompatible). It is expected that the incompatible (mirroring) responses will be executed slower than the compatible (copying) responses and that the reaction time in the third part of the task will be higher than those of part 1 and 2 because shifting attentional flexibility can be obtained by calculating the mean RT differences between compatible trials in the third part and compatible trials of the first part of the task with higher values indicating more difficulties with shifting attention. Discrepancy in reaction time (in ms) and accuracy (percentage/number of errors) between the third part and the first part of the task (flexibility) and of the second part and the first part (inhibition) were the outcome parameters and were included in statistical analyses [44,45]. Over the years, thousands of healthy children,adolescents, adults and elderly people were tested with the ANT. Based on these data nonlinear regression equations were derived by the reaction time/number of errors and the associated standard deviations described as a function of age. With these functions, the norm values with associated standard deviations, in an uninterrupted continuum age were published [36].

Questionaire

Parents were requested to administer the Brain Injury Alert (BIA). The Brian Injury Alert (BIA) was developed as a multidimensional screening tool, meant as a supportive aid in the clinical interview, of cognitive domains as well as of emotional and social consequences of paediatric TBI. The BIA was found to be a valid and reliable outcome measure in paediatric ABI [46,47].

The BIA consists of 10 items covering the cognitive domain and 9 covering the emotional and social domain. Each item contains a description of the problem in terms of "the child has difficulty with" illustrated with at least three examples of functioning in daily life. For each item the presence (scoring 1 or 0, respectively) can be indicated and the severity is scored (e.g. yes, the problem is present and it interferes with the development of the child; yes, the problem is present and but is not interfering with the development of the child; the problem is not present; or not sure whether there is an actual problem and there is some doubt. The leading rule for all items is that "the child has difficulty with… compared to age mates." For the purpose of this study both domains were included and the scores were dichotomized as 1 (problem present; either interference with development or not) and 0 (problem absent, either not present or doubtful). The results are presented as numbers (percentages) of problems present at this moment.

Statistical Analyses

All statistical analysis was conducted with SPSS 21.0 [48]. Participants were divided in groups according to age group (≤ 14 y *vs.* >14 y), type (TBI *vs.* NTBI) and severity (mild vs moderate/severe) of injury as independent variables. Dependent variables were a) Results of the Brain Injury Alert, reported in numbers and percentages; b) ANT measures of accuracy (error rate: misses+false alarms), information processing speed (reaction time of correct responses: mean of reaction time hits and reaction time correct rejections), and performance stability (SD of reaction time correct), reported in Z-scores. ANT-scores rangd of ≤ 1 SD below the mean (better performance), mean performance ≤ 1 Z>1 to ≥ 1 SD above the mean (worse performance) [38]. P-values were calculated with independent t-test, to compare the differences between subgroups.

Results

One hundred and three (103) participants completed the ANT assessment and 99 parents filled in the complete BI alert. They were part of a larger cross-sectional two-year follow-up study on outcome of ABI. Comparisons between participants in this follow-up study (n=147) and all invited patients (n=433) showed no significant differences regarding the distribution in age groups and types of injury. The number of BIA is lower, because some young adults arrived at the assessments without parents or did not give Informed Consent for administration of questionnaires by their parents.'Comparisons between participants in the follow-up study (n=147) and all invited patients (n=433) showed no significant differences regarding the distribution in age groups and types of injury. The number of BIA is lower, because some young adults arrived at the assessments without parents or did not give Informed Consent for administration of questionnaires by their parents (Table 1).

Table 1 shows the characteristics of the 103 included participants with ABI and their parents. In the TBI group (78% of participants) the severity ratio mild versus moderate/severe was 78:22. In the NTBI group (22%) the severity ratio mild versus moderate/severe was 86:12, of 2 (2%) participants data about severity were missing in the medical file. In the total ABI group 23 cases (22%) reported pre-injury health

problems versus 36 cases (35%) with health problems 2 years after onset of ABI. Parents reported a low educational level in 12 cases (12%) versus intermediate in 40 (39%) and high in 43 (42%) cases. Being a single parent household was reported by 30 (30%) parents (Table 2).

	Values N (%)	Missing values n (%)
Socio-demographic characteristics		
Age at onset in years; median (range)		0
≤ 14 y	60. (58.3)	
>14 y	43 (41.7)	
Gender		0
Boys	58 (56.3)	
Girls	45 (43.7)	
Type of injury		0
TBI total; number (% of total ABI)	80 (86.4)	
NTBI total; number (% of total ABI)	23 (22.3)	
Severity of injury[1]		2 (1.9)
Mild	89 (86,4)	
Moderate/severe	12 (11.7)	
Pre-injury problems in physical		5 (4.9)
or mental health	23 (22.3)	
Actual problems in physical		3 (2.9)
or mental health	36 (35.0)	
Educational level of parents; number (%)		8 (7.8)
Low[2]	12 (11.7)	
Intermediate	40 (38.8)	
High	43 (41.7)	
Single parent household; number (%)	30 (29.1)	7 (6.8)

y=years; TBI=Traumatic Brain Injury; NTBI=Non Traumatic Brain Injury
[1] Severity of TBI determined by means of the Glasgow Coma Scale (GCS) at hospital admission, severity of NTBI determined by means of a disability scale based on the Modified Rankin Scale (mRS) at hospital discharge
[2] Low (pre-vocational practical education or less), intermediate (pre-vocational theoretical education and upper secondary vocational education) or high (secondary education, higher education and/or university level education)

Table 1: Characteristics of the patients with acquired brain injury and their parents.

Table 2 shows the scores of the cohort on the 2 ANT tasks. Regarding Processing Speed age (older group>younger group), type (NTBI>TBI) and severity (moderate/severe>TBI) consistently determined worse results compared to the norm group without neurocognitive deficits. Between subgroups per category significant differences were found in type (NTBI<TBI) on reaction time and stability and in age (older<younger) on stability. In Attentional flexibility age (older group), type (NTBI) consistently determined worse speed (time) and accuracy (more errors) compared to the norm group without neurocognitive deficits. Between subgroups per category significant differences were found in age (older<younger) in required time. The cohort scored consistently better on accuracy (less errors) compared to the norm group without neurocognitive deficits, but needed more time (except for the younger group). Between subgroups per category significant differences were found in Inhibition time for age (older < younger) (Table 3)

Table 3 shows that between 49 and 87.3% of the group scored within 1 SD compared to the norm group without neurocognitive problems. On the Attentional tasks the study cohort responded relatively more accurate and slow. A significant proportion of the sampled population scored ≥ 1 SD above the mean (worse performance) compared to the norm group (Table 4).

On the BIA (see Table 4) 1 or more cognitive problems were reported by 62 (65%) of the parents, 1 or more social emotional problems by 66 (69%) and 1 or more cognitive and social emotional problem by 70 (77%). A higher percentage of parents endorsed cognitive, social emotional or cognitive and social emotional problems associated with age group (young>old), type (NTBI>TBI) and severity (moderate/severe>mild) of injury.

Discussion and Conclusion

Approximately 2 years after onset of ABI neurocognitive problems were assessed in a cohort of children and youth with a hospital-based diagnosis of ABI, aged 4 up to 20 years at onset of ABI, using the Amsterdamse Neuropsychological Tasks (ANT) and the parent reported Brain Injury Alert (BIA).

The cohort responded relatively more accurate and slow compared to the norm group without neurocognitive deficits. Scores on the ANT task Processing Speed varied strongly compared to the norm group

		Age group			Type of injury			Severity of injury		
		≤ 14 y n=59	>14y n=44	p	TBI n=80	NTBI n=23	p	Mild n=89	moderate/severe n=12	p
Processing Speed [3]	Simple reaction time M (SD)	-0.07[4] (1.58)	0.08 (1.09)	**0.04**	-0.19 (0.98)	0.63 (2.22)	**0.01**	-0.06 (1.44)	0.36 (1.01)	0.68
	Stability time M (SD)	-0.04 (1.15)	0.41 (0.89)	0.59	0.00 (0.80)	0.67 (1.63)	**0.01**	-0.12 (1.09)	0.26 (0.91)	0.34
Attention [5]	Flexibility time M (SD)	-0.45 (1.8)	0.76 (1.61)	**0.00**	-0.07 (1.67)	0.51 (2.25)	0.19	-0.08 (1.90)	-0.16 (1.31)	0.66
	Flexibility errors	-0.39 (2.3)	0.54 (4.28)	0.16	-0.14 (3.24)	0.54 (3.56)	0.39	-0.05 (3.51)	0.29 (1.72)	0.75
	Inhibition time M (SD)	-0.10 (1.23)	1.44 (1.63)	**0.00**	0.49 (1.67)	0.78 (1.33)	0.44	0.63 (1.66)	-0.01 (1.12)	0.20
	Inhibition errors	-0.10 (2.16)	-0.38 (2.80)	0.57	-0.17 (2.56)	-0.39 (1.96)	0.70	-0.16 (2.57)	-0.64 (1.25)	0.53

[1] a z-score is a measure of how many standard deviations below or above the population mean a raw score is.
[2] p-value calculated with independent t-test, to compare the differences between the groups.
[3] ANT subtask were completed using the dominant hand; Speed is simple reaction time in ms; Stability=within subject standard deviation on different tasks;
[4] Positive score meaning slower (time) or less accurate (errors) than norm group without neurocognitive problems; negative score meaning faster (time) or more accurate (errors) than norm group without neurocognitive problems
[5] Inhibition accuracy=percentage of errors; Flexibility accuracy=percentage of errors

Table 2: Z-scores[1] on 2 subtests of the Amsterdam Neuropsychological Tasks (ANT), related to age group, type and severity of injury.

n=103	≤ 1 SD (better)	-1 SD>Z<1 SD	≥ 1 SD (worse)
Attention Simple reaction time	16 (15.7%)	69 (69.6%)	15 (14.7%)
Stability	0 (0%)	89 (87.3%)	14 (12.7%)
Attention Flexibility speed	23 (22.5%)	53 (52%)	23.5 (25.5%)
Flexibility accuracy	30 (29.4%)	51 (49%)	22 (21.6%)
Inhibition speed	14 (13.7%)	55 (51.9%)	39 (38.2%)
Inhibition accuracy	31 (30.4%)	51 (49%)	21 (20.6%)

[1] Z-score is a measure of how many standard deviations below or above the population means a raw score is. Z-scores range from -3 standard deviations (SD) (which would fall to the far left of the normal distribution curve) to +3 SD (which would fall to the far right of the normal distribution curve).

Table 3: Z-scores[1] of the total cohort on 2 subtests of the Amsterdam Neuropsychological Tasks (ANT).

		Age group		Severity of injury[1]		Type of injury	
	Total n=99	**≤ 14 y**	**>14 y**	**Mild**	**Moderate Severe**	**TBI**	**NTBI**
Cognitive problems number (%)							
0	33 (34.7)	19 (33.9)	14 (35.9)	28 (34.6)	4 (33.3)	30 (41.7)	3 (13)
1	3 (3.2)	2 (3.6)	1 (2.6)	3 (3.7)		2 (2.8)	1 (4.3)
≥ 1	62 (65.3)	37 (66.1)	25 (64.1)	53 (65.4)	8 (66.7)	42 (58.3)	20 (87)
≥ 2	59 (62.1)	35 (62.5)	24 (61.5)	50 (61.7)	8 (66.7)	40 (55.5)	19 (82.7)
Emotional or social problems							
0	29 (31.2)	13 (24.1)	16 (41.0)	26 (32.5)	2 (18.2)	24 (34.4)	5 (21.7)
1	10 (10.8)	9 (16.7)	1 (2.6)	7 (8.8)	3 (27.3)	9 (12.9)	1 (4.3)
≥ 1	66 (68.8)	41 (75.9)		54 (67.5)	9 (81.8)		18 (78.3)
≥ 2	56 (58.1)	32 (59.2)	22 (56.4)	47 (58.7)	6 (54.5)	37 (52.8)	
Total cognitive and social emotional problems							
0	21 (23.1)	9 (17.0)	12 (31.6)	18 (23.1)	2 (18.2)	18 (26.5)	3 (13)
1	7 (7.7)	6 (11.3)	1 (2.6)	6 (7.7)	1 (9.1)	6 (8.8)	1 (4.3)
≥ 1	70 (76.9)		26 (68.4)	60 (76.9)	9 (81.8)	50 (73.5)	
≥ 2	63 (69.2)	38 (71.7)	25 (65.8)	54 (69.2)	8 (72.7)	44 (64.7)	19 (82.7)

[1] Severity of TBI determined by means of the Glasgow Coma Scale (GCS) at hospital admission, severity of NTBI determined by means of a disability scale based on the Modified Rankin Scale (mRS) at hospital discharge
[2] TBI=Traumatic Brain Injury; NTBI=Non Traumatic Brain Injury

Table 4: Parent reported problems on the brain injury alert, specified for age group, type and severity of injury.

without neurocognitive problems, worse results were associated with age (older group>younger group), type (NTBI>TBI) and severity (moderate/severe>TBI), with in subgroups significant differences in type (NTBI<TBI) on reaction time and stability and in age (older<younger) on stability. On the ANT task Attentional flexibility a large variation in scores was found as well compared with the norm group, worse results were associated with age (older<younger) and type (NTBI<TBI), with in subgroups significant differences in age (older<younger) in required time.

On the Attentional tasks the study cohort responded relatively more accurate (accuracy 29.4-30.4%, >1 SD) and slow (inhibition speed 25.5-38.2%, > 1 SD) compared to the norm group without neurocognitive deficits.

One or more cognitive problems were reported by 62 (65%) of the parents on the BIA, 1 or more social emotional problems by 66 (69%) and 1 or more cognitive and social emotional problem by 70 (77%), associated with age group (young>old), type (NTBI>TBI) and severity (moderate/severe>TBI).

The 1st hypothesis of this study, that type (NTBI versus TBI) and severity (moderate/severe versus mild) of injury would be associated with worse neurocognitive outcome were both confirmed in professional assessed (ANT) and parent reported (Brain Injury Alert) results. Lower age group (versus older age group) was associated with worse neurocognitive outcome was confirmed in the parent reported (BIA) as well, but contradicted in the neuropsychologicaly assessed (ANT) results. The 2nd hypothesis, that parents report more neurocognitive problems than professionals, was confirmed as well.

The trend in the results of this study were similar with other studies according type and severity and age as associated with neurocognitive consequences following pediatric ABI [17-19,24,25]. Early detection of these neurocognitive problems IA important to enable child-based rehabilitation, school-based assistance and parent support, critical to optimize recovery and outcome for the injured child [19].

Several limitations of our study should be noted. First, the generalizability of the results is probably limited by the small number of participants and a relatively small number of children with moderate/severe ABI and with NTBI, the latter related to the selection of the cohort. Patient recruitment was done in hospitals and not in the rehabilitation setting. Therefore, the population of in particular patients with TBI consisted predominantly of patients with mild ABI, not requiring treatment. The results are therefore not generalizable to groups of patients with ABI who are currently treated for the consequences, for example in rehabilitation. According to literature approximately 20% of children with mild TBI is hindered by consequences after 3 months and 10% after 12 months, respectively [19]. Differences with other studies may be explained by these limitations.

Moreover, the relatively high number of non-responders may indicate the presence of selection bias; however, we did not

systematically record the reasons for non-participation. Some of the non-response was due to wrong addresses, and is probably random. Although response bias cannot be excluded, the characteristics of the patients participating in the present follow-up study are fairly similar to those of the larger population, which was described in a previous publication [32,33]. Nevertheless, the relatively low response resulted in an overall small sample size, which may have limited the statistical power of the study. In addition, in future research yielding subgroups with sufficient sample sizes, more advanced statistical analyses could be employed to minimize non-response bias [49].

With regard to the parent reported neurocognitive functioning we used the BIA, which has only been found to be a reliable and valid measure in pediatric TBI, but not in NTBI. However, at the time the study was designed, it was considered the best available quantitative instrument in Dutch language, providing a parent report in all diagnosis groups. As well the ANT and BIA were originally developed in the Netherlands and hardly used in international studies. Therefore, the ANT and BIA results can not be compared with results in international studies. Another limitation of the BIA is that administration required average to higher Dutch language competencies, whereas some parents (about 10%) were not native Dutch speaking. When using the BIA as an interview instead of a questionnair, especially in this group with also parent who can't speak Dutch very well, will give the opportunity to ask more detailed about the problems wich are or are not experienced.

Another limitation of our study was that we did not gather information from school. In this cohort, with relatively many children without consequences after mild TBI and 2 years after onset, we concluded to avoid embaressment of parents due to the fear for stigmatisation and labeling by the teacher.

Furthermore, neurocognitive functioning is a complex construct with numerous interwoven determinants, many of which are likely influence the outcomes of interest in this study. In this study we focused on speed of information processing and attention and analysed the results of only 2 subtests of the ANT, possibly resulting in information bias.

To overcome these shortcomings, a larger scale and longitudinal study including sufficient numbers and proportions of children with mild, moderate and severe TBI and NTBI would be needed, using recommend outcome measures and measuring in 3 perspectives (parents, school, neuropsychologist) [50].

Conclusion

Neurocognitive problems were found in this hospital-based cohort of children with ABI, especially in the older age and NTBI group, with parents reporting strikingly more problems than professionals A multi perspective screening and assessment of neurocognitive conseuences of ABI is recommended to get a more complete and ecological valid impressions of the childs' functioning, activities and participation.

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Declaration of Interest Statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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