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Characteristics of Diagnosed Concussions in Children 0-4 Years of Age Presenting to a Large Pediatric Healthcare Network

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Abstract

Objective: To comprehensively describe the natural history of concussion in early childhood between 0 and 4 years.

Methods: Retrospective cohort study of 329 patients ages 0-4 years, with an ICD-9-CM concussion diagnosis in the Children's Hospital of Philadelphia (CHOP) healthcare network from October 1, 2013 to September 30, 2015. Clinical data was abstracted from the CHOP electronic health record (EHR) which captured all clinical care visits and injury characteristics.

Results: Nearly 9 out of 10 of patients (86.6%) sought care in the emergency department or urgent care setting, most commonly on the day of injury (56.2%) and as a result of a fall (64.4%). Over two thirds (64.4%) of patients or their parent/caregiver reported somatic symptoms (i.e. vomiting or headache) while close to half (49.2%) reported sleep issues. One in five identified emotional symptoms (21.9%) or visio-vestibular dysfunction (20.4%). Many patients also experienced symptoms not included in standard assessment tools including personality changes (34.0%) and change in appetite (12.8%).

Conclusions: These results provide insight into the clinical characteristics of concussion in early childhood up to 4 years of age. Since assessment in this group relies heavily on parent/caregiver symptom reporting, rather than patient self-report, these results will aid clinicians with the challenge of diagnosing concussions in this population. These findings highlight the need to

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develop additional tools to adequately and systematically assess common signs and symptoms of concussion in early childhood that may not be included in standard assessment scales routinely used in older adolescents and adults.

Keywords

pediatric; concussion; traumatic brain injury

Introduction

Concussion, or mild traumatic brain injury (mTBI), is a common injury, with national estimates of more than 2 million TBI-related outpatient visits to the emergency department (ED) in 2014, of which 812,000 occurred in children 0-17 years of age.¹ In recent years there has been increased attention centered on concussion; however, it has been mostly focused on sports concussions in older youth and young adults, with less attention on the concussion burden in early childhood, especially those 0-4 years of age. Children ages 0-4 have the highest rates of ED visits for TBI of all severities across the pediatric age span^{1,2} and have increased risk compared with older children for ongoing cognitive and behavioral effects of TBI because of their developmental stage.²⁻⁹ Recent reports have documented differences in cognitive functioning, behavioral regulation, and emotional functioning in young children within and beyond the first year post-TBI, including mTBI,¹⁰⁻¹² highlighting the importance of recognition and diagnosis at the time of injury. Much of the research in early childhood has focused on moderate-to-severe TBI, with less attention on the burden of concussion on children in this age group.

Young children who experience concussion pose a unique diagnostic challenge for clinicians due to the developmental limitations on subjective patient symptom recognition and report, the mainstay of concussion diagnosis. Tools developed for concussion diagnosis and management have been suitably validated for older children who are capable of symptom self-report. For example, the Graded Symptom Checklist (GSC), Acute Concussion Evaluation (ACE), Post-Concussion Symptom Scale (PCSS), Post-Concussion Symptom Inventory (PCSI), and Child SCAT-5 (Sport Concussion Assessment Tool 5- Child Version) have been validated for children ages 5 and up.^{13,14} However, these assessment scales have limited usefulness for this 0-4-year age group where verbal skills are non-existent or emerging. This results in a heavy reliance on report of signs and symptoms from parents/ caregivers, who have been shown to report fewer symptoms in preschool children compared with parents of school-aged children, or only report readily observable symptoms (e.g., loss of consciousness or vomiting).^{15,16} In a study relying on parent report of symptoms, children younger than 6 years were reported to have faster resolution of concussion symptoms, compared with school-aged children, although it is not clear if this is due to differences in the injury or the limitations of parental reporting.¹⁷ In a small sample of 28 pre-school children with concussion, Suskauer et al, described a broad spectrum of reported symptoms including appetite changes, behavioral dysregulation, decreased engagement, enuresis, increased dependence, and stomachaches, which are not typically associated with concussion or included on traditional concussion symptom scales.¹⁸ A more comprehensive understanding of the characteristics of concussion in children 0-4 years of age would

improve diagnosis and management in these very young children by providing insight into the mechanisms of injury, symptom profile, typical location of presentation for care, and clinical course of care. Thus, the purpose of this study was to comprehensively describe the natural history and presentation of concussion in early childhood, specifically ages 0-4 years.

Materials and Methods

CHOP Healthcare Network

The Children's Hospital of Philadelphia (CHOP) healthcare network is a large pediatric healthcare system and includes over 50 locations across southeastern Pennsylvania and southern New Jersey. The network has over 1 million visits per year, serves a socioeconomically and racially diverse patient population, and accepts most insurance plans, including Medicaid. An electronic health record (EHR) system (EpicCare®, Epic Systems, Inc, Madison, WI) is utilized for the documentation of all clinical care throughout the CHOP network, including both inpatient and outpatient settings.

Patient Identification

We queried the CHOP EHR system to identify all individuals who had a visit for concussion at a CHOP network location from October 1, 2013 through September 30, 2015 (n=10,456). Concussion visits were defined as those assigned an International Classification of Diseases, Ninth Revision (ICD-9-CM) diagnosis code of concussion.¹⁹ Patients who had a previous concussion visit at CHOP within 6 months before their earliest visit in the study period were excluded (n=562) in order to capture the initial visit for a concussion rather than a follow-up visit for an earlier concussion. The study population was then limited to patients who were 0 to 4 years old at the time of their first study-period visit (n=335). To minimize misclassification of concussion diagnosis, we further excluded two patients who were also assigned an ICD-9-CM code for a more severe TBI (codes including the following key words/phrases: contusion, laceration, subarachnoid, subdural, epidural, other and unspecified intracranial hemorrhage, moderate [1-24 hours] loss of consciousness, prolonged [more than 24 hours] loss of consciousness) within two weeks of the initial concussion visit. This resulted in a study population of 333 patients.

EHR Abstraction

In-depth EHR abstraction was performed by a single data abstractor, trained by two study authors (RK and OP). Training included abstraction for 10 patient records until the abstractor and two trainers achieved complete agreement on all data elements. Furthermore, inter-rater reliability was found to be high (overall kappa coefficient = 0.80) between the abstractor and a trainer (OP) on a 20% sample of abstracted records. Analysis of abstracted patient records further excluded an additional 4 patients whose initial visit in the study period was not related to a concussion (e.g., head injury without concussion, history of concussion only). Thus, the final analytical sample used for this study included 329 patients age 0-4 years with a concussion diagnosis (supported by clinical EHR documentation) and care for that concussion within the CHOP network during the two-year study period.

Variable Definitions

Time to initial healthcare visit was defined as the number of days from the reported date of injury to date of initial visit (CHOP or elsewhere). Time to initial visit at CHOP was additionally calculated. The mechanism of injury was identified from the EHR. A hierarchical, structured coding system based on external cause of injury codes was used to categorize broad mechanisms of injury: falls; motor vehicle crashes (occupant or pedestrian); struck by person (unintentional); struck by object; bicycle-related; assault; not documented; unknown; or other.²⁰ Falls were further categorized into the following categories: stairs, furniture, shopping cart, slipping or tripping, being dropped while carried by person, unwitnessed or other.

We identified the initial point-of-care, any additional points-of-care, and number of healthcare visits at CHOP and elsewhere during the course of treatment. Points-of-care included: emergency department or urgent care center; primary care setting; outpatient specialty care setting (e.g., orthopedics/sports medicine, trauma, neurology); or hospital admission. Patients with imaging tests during their clinical course were identified, as well as any clinically significant imaging findings.

We abstracted from the EHR all concussion-related symptoms reported by the patient or parent/caregiver at each concussion-related visit. Symptoms from the PCSS were grouped into 5 subcategories: (1) somatic: headache, nausea, vomiting, sensitivity to light, sensitivity to noise, numbness or tingling; (2) sleep: fatigue, trouble falling asleep, sleeping more than usual, sleeping less than usual, drowsiness; (3) emotional: irritability, sadness, nervousness, feeling more emotional; (4) visio-vestibular: balance problems, dizziness, visual problems; and (5) cognitive: feeling slowed down, feeling mentally foggy, difficulty concentrating, difficulty remembering.²⁵ Any additionally documented signs or symptoms through physician narrative were abstracted: amnesia, loss of consciousness, confusion, mental status change, disorientation, slurred speech, increased/decreased appetite, increased/decreased urination, constipation/diarrhea, autonomic symptoms (pallor/cyanosis, hypotension/hypertension or orthostatic hypotension, body temperature dysregulation, intermittent apnea, and epistaxis), neck pain, tinnitus, and personality changes.

Statistical Analysis

Relevant demographic and clinical characteristics among concussion patients are described using frequencies and proportions for categorical variables and medians and interquartile ranges for continuous variables. We compared the distribution of select variables by age group (< 2 years, 2-4 years) using chi-square and Wilcoxon rank-sum tests. All analyses were conducted using SAS software, Version 9.4 (SAS Institute Inc., Cary, NC, USA). This study was reviewed and approved by the CHOP Institutional Review Board.

Results

Patient Population

A total of 329 patients ages 0-4 years were diagnosed with a concussion over the two-year study period. Our study cohort was primarily male (58.1%), non-Hispanic white (46.5%),

with private insurance (53.5%) (Table 1). The median age was 3.1 years (IQR 1.9-4.1); 27.9% were <2 years of age.

Injury Characteristics

The most common mechanism of injury was a fall (n=212, 64.4%), followed by struck by object (n=66, 20.1%) and motor vehicle crash (MVC) (n= 27, 8.2%) (Table 2). Of those injured in an MVC, 77.8% were passengers and 22.2% were pedestrians. Children <2 years of age were more likely to have sustained a concussion from a fall than children ages 2-4 (78.3% vs 59.1%, respectively, p=0.001). The most common type of fall was from furniture (n=70, 33.0%), followed by the child slipping or tripping and subsequently hitting the ground (n=42, 19.8%), and falling down stairs (n=37, 17.5%). Review of ICD-9-CM diagnosis codes for child abuse revealed that none of these patients had a diagnosis of child abuse on the same day of the concussion visit.

Clinical Course of Care

The vast majority (86.6%) sought care in an emergency department or urgent care, either within or outside the CHOP system. Most children presented to the CHOP system on the same day of injury (n= 185, 56.2%) or within the first week post-injury (n=124, 37.7%; Table 3). Day of injury presentation occurred at a slightly higher frequency among <2-year-olds (n=59, 64.1%) compared with 2- to 4-year-olds (n=126, 53.2%; p=0.07). The remainder of children largely presented within 8-28 days of injury (n=15, 4.6%) with few presenting beyond one month of injury (n=5, 1.5%). The clinical course of care for most children included 1-3 clinical visits (88.7%) while the remainder had 4-33 provider visits. Almost half of patients (n=157, 47.7%) had only a single clinical episode of care, with 85.4% (n=134 of 157) of those occurring at a CHOP ED. Children <2 years of age were more likely to have only a single clinical visit (n=56, 60.9%) compared with 2- to 4-year-olds (n=101, 42.6%, p=0.003).

A total of 137 patients (41.6%) had radiological imaging (i.e., CT, MRI, X-ray) performed during their clinical course of care. The most common imaging modality used in this age group was CT (n= 128, 38.9%), followed by X-ray (n=28, 8.5%), and MRI (n=6, 1.8%). Of those who had imaging performed, 88.3% (n=121) had normal radiological findings. 11.7% (n=16) were identified as having fractures on X-ray: skull (n=12, 75%), facial/nasal/orbital (n=2, 12.6%), and mandibular (n=2, 12.5%). By exclusion criteria, no other brain injuries in addition to the concussion were present on any of the imaging modalities.

Symptom Profile

Most patients or their parent/caregiver reported 1-3 distinct PCSS symptoms during their clinical course of care (63.1%). Only 7.9% reported 6 or more distinct PCSS symptoms; all were children 2-4 years of age. Almost two-thirds (n=212, 64.4%) reported at least one somatic symptom, while almost half (n=162, 49.2%) reported sleep symptoms (Table 4). Approximately one in five reported emotional symptoms (n=72, 21.9%) and a similar proportion had visio-vestibular symptoms noted in the EHR as noted via clinical examination or report by the patient and/or caregiver (n=67, 20.4%). Of the somatic symptoms, the most common was vomiting (n=159, 75.0%), followed by headache (n=125,

59.0%) and nausea (n=22, 10.4%). Children ages 2-4 years or their parent/caregiver reported somatic and visio-vestibular symptoms more frequently than children less than 2 years ($p<0.001$). The two most common additionally reported symptoms included personality changes (n=112, 34.0%) and increased/decreased appetite (n=42, 12.8%).

Discussion

Concussion in early childhood among children 0-4 years of age remains a diagnostic challenge for clinicians, and many may feel ill-equipped to care for concussion in this young population.^{21,22} Findings from this study, one of the most comprehensive descriptions of children 0-4 years of age with a diagnosed concussion, provide valuable insight into characteristics of concussion in this early childhood population during their course of care. Awareness of this information by clinicians may, in turn, facilitate improvements in diagnosis and clinical management.

Symptom report is the current cornerstone of concussion diagnosis, often through the use of concussion symptom scales, such as the PCSS; however, most scales have only been validated for children over the age of 5.^{23,24} In our study sample, most patients were found to have 1-3 distinct symptoms that are included on the PCSS, and those reporting the greatest number of symptoms (>6) were children 2-4 years of age. Current concussion symptom scales, like PCSS, contain abstract concepts (e.g., feeling mentally “foggy,” feeling slowed down, nervousness, difficulty concentrating) that could be difficult for very young children to comprehend or verbally express, leading to heavy reliance on parent/caregiver reports. Similar to previous work¹⁵, the fewer number of symptoms reported in those less than 2 years in our study may suggest either a lower symptom burden or under-reporting or under-recognition of symptoms by parents/caregivers for the youngest children in our cohort.

Our study found that children 0-4 years of age do present with similar symptom categories as older children and adolescents. Almost one-third of patients reported at least one somatic symptom, with almost half of patients reporting sleep symptoms, similar to findings by our group in older children.²⁵ Further, visio-vestibular symptoms were also common in our study sample (20.4%). Previous studies by our group have shown the visio-vestibular exam can be reliably completed in those as young as 10 years and by approximately 50% of 6-year-olds.^{26,27} While clinicians may attempt to assess these deficits in 2-4 year-olds, developmental limitations present a challenge in testing this population (e.g., assessing balance and eye tracking).

Importantly, our study confirms and extends the work of others^{15,17,18} by examining a larger cohort of concussed patients in early childhood and adding a description of concussion in children less than 2 years of age. The results reinforce previous findings¹⁵ that patients and/or parents/caregivers will often report symptoms not commonly captured on standard concussion symptom scales, with “personality change” as the most common in our study. Other behavioral changes reported by parents/caregivers included increased crying, increased neediness or attachment to parent/caregiver, increased meltdowns, regressive behaviors, decreased interaction, and increased frustration. Additional symptoms reported

that are not part of typical concussion scales include increased/decreased appetite, increased/decreased urination, urination accidents, and constipation/diarrhea. These types of symptoms are not frequently reported among cohorts of older children, highlighting the importance of incorporating a behavioral change assessment into the clinical concussion assessment in very young children. These findings support the need for the establishment of developmentally appropriate diagnostic tools tailored to early childhood. Symptom scales for very young children should include common concussion symptoms observed across all ages, but should also include additional symptoms specifically observed in this age group in order to improve the recognition, diagnosis and management of concussion.

Our study also found that more than three-fourths of patients diagnosed with a concussion presented to the ED or urgent care for initial care; the majority presented on the same day of injury, especially those <2 years of age. The remaining patients generally presented within one week of injury. These findings confirm previous work done by our group; the most common point of entry into the CHOP healthcare network for this age group was found to be the ED followed by the primary care setting.¹⁹ Those less than 2 years of age are at risk for skull fractures and more serious brain injuries,^{28,29} and their most commonly-experienced symptoms of concussion (e.g., vomiting) could also be suggestive of a more serious traumatic brain injury, prompting parents to seek immediate evaluation in an ED.

In this setting, clinicians often rely on radiological imaging to exclude more serious TBI or trauma, particularly in very young children. Consequently, it is not surprising that a large proportion of our study sample received radiological imaging, even though the majority (88.3%) were found to have normal radiological findings. The use of head injury clinical decision rules has made significant headway in decreasing unnecessary radiation exposure for children,^{30,31} however, they are not intended for use in children under the age of 2 years. Further research is needed to determine if there are well-defined circumstances in the 0-2 year population where imaging can be avoided.

Due to recent increased public awareness, pediatric concussion is often thought of primarily in relation to organized sports. However, children 0-4 years of age engage in different types of activities resulting in different mechanisms of injury compared with older children.²⁰ Broadly, the most common mechanism of injury in our study population was a fall, which is consistent with prior literature.^{1,32} The most frequent fall scenarios that provide an opportunity for injury prevention were those from furniture or down stairs and these data suggest providers should consider evaluation for a concussion whenever children present with these injury histories. This pattern of injury in this age range also provides potential opportunities for prevention, such as anticipatory guidance regarding the need for gates at the top of stairs in homes with young children.

There are several limitations to note for this study. First, as a retrospective cohort study, data variables were not collected as systematically as in a prospective study. Consequently, the frequency of particular symptoms may be underrepresented if they were not uniformly assessed especially for those symptoms that are not part of common scales such as the PCSS. In addition, symptom prevalence, specifically vestibular symptoms, may be a

conservative estimate for this population as most children in this age range present to the ED and may not be systematically assessed. However, shortly before the beginning of our study period, CHOP implemented clinical decision support tools into the EHR and network wide training to increase systematic symptom assessment and clinical documentation of concussion care.³³ Second, our sample may not be generalizable to all early childhood concussion since it only includes children who sought some type of care within the CHOP Network. Characteristics, clinical course, and management may differ among children seen outside of the CHOP healthcare network. The sample primarily represents a suburban and urban population with access to a specialized children's hospital and pediatric ED, which may not be representative of all geographic areas. Third, the study used ICD-9-CM diagnostic codes in the EHR to identify concussed patients. The lack of clear diagnostic criteria for concussion in young children may have resulted in providers erroneously using other diagnosis codes or misdiagnosing cases of concussion, thus resulting in our study potentially missing some true concussions.

In summary, this study is the most comprehensive characterization of concussion in early childhood, 0-4 years, to date. Despite improvements to concussion diagnosis and management in older children and adolescents, young children with concussion remain a diagnostic challenge. Importantly, while young children frequently present with symptoms similar to those observed in their older counterparts, many experience symptoms not included in tools validated for older ages. In addition, unlike older children, the diagnosis of concussion in children 0-4 years relies heavily on parent/caregiver symptom reporting. Symptoms commonly reported in very young children include changes in behavior, personality, appetite, and urinary/gastrointestinal systems; standardized assessment tools for concussion in early childhood should be developed so as to account for these symptoms. While clinicians can diagnose concussion in early childhood using existing tools validated for older children, assessment of these additional symptoms observed in this very young age group may further support the diagnosis, thereby improving identification and management of concussion in this vulnerable population.

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Abbreviations:

TBI	Traumatic Brain Injury
mTBI	Mild Traumatic Brain Injury
ED	Emergency department
CHOP	Children's Hospital of Philadelphia's
EHR	Electronic Health Record

ICD-9-CM	International Classification of Diseases, Ninth Revision
SCAT 5	Sport Concussion Assessment Tool 5
PCSS	Post-Concussion Symptom Scale
IQR	Interquartile Range

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Table 1.

Characteristics of patients 0-4 years of age with concussion diagnoses, Children's Hospital of Philadelphia healthcare network, 2013-2015 (n=329)

Characteristic	N	Column %
Age at concussion (years)		
<1	36	10.9
1	56	17.0
2	65	19.8
3	84	25.5
4	88	26.7
Sex		
Female	138	41.9
Male	191	58.1
Race/ethnicity		
Non-Hispanic White	153	46.5
Non-Hispanic Black	104	31.6
Hispanic	27	8.2
Non-Hispanic Multiple/Other	18	5.5
Unknown	27	8.2
Insurance payor		
Medicaid	135	41.0
Private	176	53.5
Self-pay	18	5.5

Table 2.

Mechanism of injury in patients 0-4 years of age diagnosed with concussion (n=329)

Mechanism	Total (n=329)		<2 years (n=92)		2-4 years (n=237)	
	N	Column %	N	Column %	N	Column %
Fall	212	64.4	72	78.3	140	59.1
Furniture	70	33.0	33	44.4	38	27.1
Slip/trip action	42	19.8	11	15.3	31	22.1
Stairs	37	17.5	16	22.2	21	15
Struck by object	66	20.1	10	10.9	56	23.6
Motor vehicle crash	27	8.2	7	7.6	20	8.4
Struck by person	11	3.3	2	2.2	9	3.8
Bicycle-related	6	1.8	0	0	6	2.5
Other	7	2.1	1	1.1	6	2.5

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Table 3:

Characteristics of clinical care in patients 0-4 years of age diagnosed with concussion (n=329)

Clinical Care Characteristics		Total (n=329)		<2 years (n=92)		2-4 years (n=237)	
		N	Column %	N	Column %	N	Column %
Providers: CHOP or Outside Hospital Healthcare Network	ED/ Urgent Care	285	86.6	85	92.4	200	84.4
	Primary Care	127	38.6	24	26.1	103	43.5
	Specialty Care	33	10	6	6.5	27	11.4
Presentation to the CHOP Network in Days from Injury	0	185	56.2	59	64.1	126	53.2
	1-7	124	37.7	30	36.2	94	39.7
	8-28	15	4.6	2	2.2	13	5.5
	29+	5	1.5	1	1.1	4	1.7
Length of Care: Total Number of Provider Visits	1	157	47.7	56	60.9	101	42.6
	2	88	26.7	22	23.9	66	27.8
	3	47	14.3	9	9.8	38	16
	4	19	5.8	3	3.3	16	6.8
	5	10	3	1	1.1	9	3.8
	6-33	8	2.5	1	2.4	7	2.8
Radiological Imaging During Clinical Care *	CT	128	38.9	36	39.1	92	38.8
	MRI	6	1.8	1	1.1	5	2.1
	X-Ray	28	8.5	8	8.7	20	8.4
	None	192	58.4	52	56.5	140	59.1

* Percent of all patients; imaging modalities not mutually exclusive, some patients had multiple imaging studies

CHOP=Children's Hospital of Philadelphia

Table 4.

Reported symptoms in patients 0-4 years of age diagnosed with concussion, grouped by Post-Concussion Symptom Scale (n=329) category and age

Symptom Category	Total (n=329)		<2 (n=92)		2-4 (n=237)		P-value
	N*	%	N*	%	N*	%	
Somatic (headache, nausea, vomiting, sensitivity to light, sensitivity to noise, numbness or tingling)	212	64.4	42	45.7	170	71.7	<0.001
Sleep (fatigue, trouble falling asleep, sleeping more than usual, sleeping less than usual, drowsiness)	162	49.2	42	45.7	120	50.6	0.42
Emotional (irritability, sadness, nervousness, feeling more emotional)	72	21.9	25	27.2	47	19.8	0.15
Visio-vestibular (balance problems, dizziness, visual problems)	67	20.4	6	6.5	61	25.7	<0.001
Cognitive (feeling slowed down, feeling mentally foggy, difficulty concentrating, difficulty remembering)	20	6.1	0	0	20	8.4	0.004

*Patients can report symptoms in more than one category; percentages do not add to 100%.

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