ARTICLE

Presentations and Outcomes of Children With Intraventricular Hemorrhages After Blunt Head Trauma

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Objective: To describe the clinical presentations and outcomes of children with intraventricular hemorrhages (IVHs) after blunt head trauma (BHT).

Design: Subanalysis of a large, prospective, observational cohort study performed from June 1, 2004, through September 31, 2006.

Setting: Twenty-five emergency departments participating in the Pediatric Emergency Care Applied Research Network.

Patients: Children presenting with IVH after BHT.

Exposure: Blunt head trauma.

Main Outcome Measures: Clinical presentations and outcomes, including the Pediatric Overall Performance Category (POPC) and Pediatric Cerebral Performance Category (PCPC) scores at hospital discharge.

Results: Of 15 907 patients evaluated with computed tomography, 1156 (7.3%) had intracranial injuries. Forty-three of the 1156 (3.7%; 95% CI, 2.7%-5.0%) had nonisolated IVHs (ie, with intracranial injuries on computed tomography), and 10 of 1156 (0.9%; 95% CI, 0.4%-1.6%) had isolated IVHs. Only 4 of 43 (9.3%) of those with nonisolated IVHs had Glasgow Coma Scale (GCS) scores of 14 to 15, and all 10 (100.0%) with isolated IVHs had GCS scores of 15. No patients with isolated IVHs required neurosurgery or died. One patient had moderate overall disability (by the POPC score), and no patient had moderate or severe disability at discharge (by the PCPC score). Of the 43 patients with nonisolated IVHs, however, 16 (37.2%) died and 18 (41.9%) required neurosurgery. In 27 patients (62.8%), injuries ranged from moderate overall disability to brain death by the POPC score.

Conclusions: Children with nonisolated IVHs after BHT typically present with GCS scores of less than 14, frequently require neurosurgery, and have high mortality rates. In contrast, those with isolated IVHs typically present with normal mental status and are at low risk for acute adverse events and poor outcomes.

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BLUNT HEAD TRAUMA (BHT) IS one of the most common reasons for children to be evaluated in emergency departments (EDs).[1] Depending on a variety of factors, including the specific mechanisms of BHT, a wide range of intracranial injuries (ICIs) and outcomes after BHT are observed.[1,2] Computed tomography (CT) is the diagnostic tool most commonly used to evaluate children promptly after BHT.[3-5] Although prompt CT provides specific information regarding the anatomical location of the ICI if present, it provides limited information on the functional consequences of identified lesions.[4,6-8]

Intraventricular hemorrhage (IVH) is a type of injury uncommonly seen in adults or children undergoing cranial CT after head trauma.[9] The reported prevalence of IVH in patients with BHT undergoing cranial CT is 1.4%.[10] As a consequence of its infrequency, there is limited information regarding the clinical presentations and outcomes of children with traumatic IVHs. Most reported cases of traumatic IVHs are secondary to severe mechanisms of injury and have poor outcomes. Atzema et al,[10] in a large multicenter study of adult and pediatric BHT, found that 70% of patients with IVHs had Glasgow Outcome Scale scores of 1, 2, or 3 (poor outcome). Similarly, Kobayashi et al[11] described 4 pe-

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diatric patients with IVHs after severe mechanisms of injury, 2 of whom died of their injuries.

Most reported cases of IVHs are also associated with other ICIs.[10,12,13] The cause of reported poor outcomes in patients with IVHs and other associated head injuries is unclear but may be a consequence of intraventricular blood migrating from nearby mechanically disrupted tissues. Intraventricular hemorrhages in association with other ICIs, such as subdural hematomas, shearing injuries, brain contusions, and intracerebral hemorrhages, may be a marker of greater injury to the brain and poor prognosis.[12] It is unclear, however, whether IVHs that are *isolated* (ie, without other ICIs visible on CT) have the same clinical significance. The goal of this study was to describe the prevalence, clinical presentations, and outcomes of children with traumatic IVHs in a large study of pediatric head trauma. We hypothesized that IVHs are seen uncommonly in children after minor BHT (defined by Glasgow Coma Scale [GCS] scores of 14-15), and children with isolated IVHs are at low risk for adverse outcomes.

METHODS

STUDY SETTING AND POPULATION

We performed a subanalysis of a large prospective cohort study of children younger than 18 years with BHT who presented to any of the 25 hospital EDs participating in the Pediatric Emergency Care Applied Research Network (PECARN) from June 1, 2004, through September 31, 2006. The study was approved by the institutional review boards at all participating sites and at the institutional review board of the university for the Data Coordinating Center. Study methods have been previously described in detail.[14] In brief, we enrolled patients with BHT who presented to one of the participating EDs within 24 hours of the traumatic event. Patients with trivial mechanisms of injury (eg, ground-level falls or running into stationary objects) without signs of traumatic brain injury (TBI) were excluded. We also excluded patients with penetrating trauma, ventricular shunts, bleeding disorders, or previous neuroimaging. Specific methods pertinent to this subanalysis are provided in the following paragraphs.

STUDY INCLUSION AND EXCLUSION CRITERIA

We analyzed the subset of children who underwent cranial CT as part of their ED evaluation, and the site radiologist confirmed any abnormal collection of blood within the ventricular system. If there was more than 1 CT scan performed, we used the scan that most definitively described the IVH(s). Equivocal CT scans were adjudicated by a senior faculty study pediatric radiologist (S.L.W.-G.) at the primary study site. One patient was excluded because the Pediatric Overall Performance Category (POPC) and the Pediatric Cerebral Performance Category (PCPC) functional outcome scores were not available.

We compared patients with isolated IVHs with those with nonisolated IVHs with regard to clinical presentations and outcomes. We defined an *isolated* IVH as a CT-identified IVH alone without any other intracranial injury (with or without linear skull fractures). We defined a *nonisolated* IVH as an IVH in association with at least 1 other ICI on CT. We defined an *ICI* as any traumatic intracranial finding on CT except for isolated linear skull fractures. These ICIs could be any of the following: an intracranial hemorrhage or contusion, cerebral edema, traumatic infarction, diffuse axonal injury, shearing injury, sigmoid sinus thrombosis, midline shift of intracranial contents or signs of brain herniation, diastasis of the skull, pneumocephalus, and depressed skull fracture at least the width of the table of the skull.

We collected clinical data, including patient age, sex, mechanism of injury, history of loss of consciousness, history of vomiting, and initial presenting GCS score. Severe mechanism of injury was defined by motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by motorized vehicle; falls greater than 3 ft for children younger than 2 years and greater than 5 ft for children 2 years and older; or head struck by a high-impact object. The CT scans that showed IVHs were reviewed to describe location and number of ventricles containing hemorrhages.

OUTCOME MEASURES

The primary outcome of interest was an acute adverse event defined as death from TBI, neurosurgical intervention, or intubation for greater than 24 hours for management of the head injury. Patients who were hospitalized were followed up to determine outcomes; those discharged to home from the ED received telephone or mail follow-up to determine subsequent CT imaging, hospitalization, or neurosurgical intervention for a TBI. For those not available by telephone or mail follow-up, we reviewed the patients' medical records, ED quality improvement records, trauma registry records, and the county morgue records to identify any patients who were lost to telephone or mail follow-up and who may have had a clinically important TBI. The secondary outcome of interest was patient functional status at hospital discharge, which was determined by information collected during medical record review, using the POPC and the PCPC scores.[15] These scoring systems use a 6-point ordinal scale rating functional outcomes from 1 (normal; good overall performance) to 6 (brain death). We defined poor functional outcome as a score of 3 to 6 (ie, moderate or severe disability, coma or vegetative state, or brain death).[5,16]

STATISTICAL ANALYSIS

We described the study population using simple descriptive statistics, with 95% CIs where appropriate. We examined the association of each clinical presentation and outcome variable with the isolated and nonisolated IVH groups using the Fisher exact test. We calculated the rate differences of acute adverse and functional outcome events and their associated 95% CIs between the isolated and nonisolated IVH groups. We performed the data analysis using SAS statistical software, version 9.2 (SAS Institute, Inc).

RESULTS

STUDY POPULATION

Of 43 904 patients enrolled in the primary study, 43 398 met inclusion criteria for the current analysis. A total of 15 907 patients (36.7%) had CTs performed, and 1156 (7.3%) had ICIs apparent on CT, including 53 (4.6%; 95% CI, 3.5%-6.0%) with IVHs, of whom 10 (0.9%; 95% CI, 0.4%-1.6%) had isolated IVHs. Therefore, of the 15 907 patients who underwent CT, the prevalence of any IVH was 53 of 15 907 (0.3%; 95% CI, 0.2%-0.4%) and the prevalence of isolated IVH was 10 of 15 907 (0.06%; 95% CI, 0.03%-0.12%). All subsequent analyses are limited to the 53 children with IVHs on CT.

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Table 1. Comparison of Clinical Factors Between Children With Nonisolated and Isolated IVHs on Computed Tomography[a]

Factor	No. (%) of Patients: Nonisolated IVH (n = 43)	No. (%) of Patients: Isolated IVH (n = 10)	*P* Value
Median age (IQR), y	8.5 (2.0-14.6)	7.7 (0.4-12.6)	
Male sex	23 (53.5)	9 (90.0)	.07
Injury mechanism			
Occupant in motor vehicle collision	12 (27.9)	4 (40.0)	.51
Pedestrian struck by moving vehicle	11 (25.6)	0	
Bike rider struck by automobile	2 (4.7)	1 (10.0)	
Bike collision or fall from bike while riding	1 (2.3)	0	
Other wheeled transport crash	2 (4.7)	0	
Fall from elevation	5 (11.6)	2 (20.0)	
Fall down stairs	2 (4.7)	1 (10.0)	
Sports	3 (7.0)	1 (10.0)	
Object struck head (unintentional)	3 (7.0)	0	
Other mechanism	2 (4.7)	1 (10.0)	
Severe mechanism of injury[b]	20 (46.5)	2 (20.0)	.17
Clinical presentation			
Vomiting	11/26 (42.3)	2/9 (22.2)	.43
History of loss of consciousness	35/38 (92.1)	6 (60.0)	.03
GCS score			
3-8	31 (72.1)	0	<.001
9-13	8 (18.6)	0	
14-15	4 (9.3)	10 (100)[c]	

Abbreviations: GCS, Glasgow Coma Scale; IQR, interquartile range; IVH, intraventricular hemorrhage.
[a] Data are presented as number (percentage) of patients unless otherwise indicated.
[b] Severe mechanism of injury was defined by motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by motorized vehicle; falls greater than 3 ft for children younger than 2 years and greater than 5 ft for children 2 years and older; or head struck by a high-impact object.
[c] All with GCS score of 15.

CLINICAL CHARACTERISTICS AT PRESENTATION

We compared the clinical characteristics at ED presentation between the patients with isolated and nonisolated IVHs (**Table 1**). Children with isolated IVHs were more likely to have GCS scores of 14 to 15, whereas children with nonisolated IVHs were more likely to present with a history of loss of consciousness. No difference was found between the 2 groups in terms of sex, history of vomiting, and severity of the mechanism of injury.

RADIOGRAPHIC FINDINGS

Descriptions of the radiographic findings of the CT scans in the isolated and nonisolated IVH groups are provided in **Table 2**. Of the 43 patients with nonisolated IVHs, 23 (53.5%) had more than 1 ventricle with hemorrhage identified on CT compared with 3 of the 10 patients (30.0%) with isolated IVHs. Among the patients with isolated IVHs, the IVH was located in at least 1 of the lateral ventricles in 7 of the 10 patients (70.0%) compared with 23 of the 43 patients (53.5%) with nonisolated IVHs.

ACUTE ADVERSE AND FUNCTIONAL OUTCOMES

Patients with isolated IVHs had better outcomes than those with nonisolated IVHs. **Table 3** details the acute adverse and functional outcomes in both patient groups. Patients with nonisolated IVHs were more likely to have intubation for more than 24 hours (rate difference, 55.8%; 95% CI, 21.7%-82.0%), neurosurgical intervention (rate difference, 41.9%; 95% CI, 7.1%-73.7%), or die due to their head injury (rate difference, 37.2%; 95% CI, 2.3%-67.2%).

Patients with isolated IVHs were also less likely to have poor functional outcomes than patients with nonisolated IVHs as assessed by both POPC and PCPC functional outcome scores. Only 1 of the 10 patients (10.0%) with isolated IVHs had a poor functional outcome based on the POPC score compared with 27 of 43 patients (62.8%) with nonisolated IVHs (rate difference, –52.8%; 95% CI, –81.3% to –19.1%). One patient with an isolated IVH with a poor functional outcome based on the POPC score had a functional outcome of moderate overall disability. None of the patients with isolated IVHs had poor functional outcomes based on the PCPC score compared with 25 of 43 patients (58.1%) with nonisolated IVHs (rate difference, –58.1%; 95% CI, –84.2% to –24.3%).

COMMENT

In this large, prospective series of children with BHT, we found the presence of IVH on CT to be an uncommon occurrence, with outcomes greatly predicated on whether the IVH was associated with other ICIs on CT. Among the patients with IVHs, 18.9% had isolated IVHs, and they typically presented with normal GCS scores and had good clinical and functional outcomes. This finding is in contrast to children with nonisolated IVHs, who presented to the ED predominantly with GCS scores of less than

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Table 2. Comparison of Radiographic Findings Between Patients With Nonisolated and Isolated IVHs on Computed Tomography

Finding	No. (%) of Patients: Nonisolated IVH (n = 43)	No. (%) of Patients: Isolated IVH (n = 10)
IVH	23 (53.5)	3 (30.0)
IVH location		
Lateral ventricles only	23 (53.5)	7 (70.0)
Third or fourth ventricles or cerebral aqueduct only	6 (14.0)	1 (10.0)
Both ventricular areas	14 (32.6)	2 (20.0)
Intracranial injuries[a]		
Cerebellar hemorrhage	3 (7.0)	0
Cerebral contusion	9 (20.9)	0
Cerebral edema	19 (44.2)	0
Cerebral hemorrhage or intracerebral hematoma	16 (37.2)	0
Diastasis of the skull	4 (9.3)	0
Epidural hematoma	4 (9.3)	0
Extra-axial hematoma	7 (16.3)	0
Midline shift	16 (37.2)	0
Pneumocephalus	11 (25.6)	0
Subarachnoid hemorrhage	25 (58.1)	0
Subdural hematoma	11 (25.6)	0
Diffuse axonal injury	4 (9.3)	0
Herniation	1 (2.3)	0
Shear injury	4 (9.3)	0

Abbreviation: IVH, intraventricular hemorrhage.
[a] More than 1 intracranial injury can be present.

Table 3. Comparison of Clinical and Functional Outcomes Between Patients With Nonisolated and Isolated IVHs on Computed Tomography

Outcome	No. (%) of Patients: Nonisolated IVH (n = 43)	No. (%) of Patients: Isolated IVH (n = 10)	*P* Value
Acute adverse and functional outcomes			
Death	16 (37.2)	0	.02
Neurosurgery	18 (41.9)	0	.01
Intubated for >24 h for ICI	24 (55.8)	0	.001
POPC score at ED or hospital discharge			
Good overall performance	10 (23.3)	8 (80.0)	.005
Mild overall disability	6 (14.0)	1 (10.0)	
Moderate overall disability	3 (7.0)	1 (10.0)	
Severe overall disability	7 (16.3)	0	
Brain death	17 (39.5)	0	
PCPC score at ED or hospital discharge			
Normal	11 (25.6)	9 (90.0)	.005
Mild disability	7 (16.3)	1 (10.0)	
Moderate disability	3 (7.0)	0	
Severe disability	5 (11.6)	0	
Brain death	17 (39.5)	0	

Abbreviations: ED, emergency department: ICI, intracranial injury; IVH, intraventricular hemorrhage; PCPC, Pediatric Cerebral Performance Category; POPC, Pediatric Overall Performance Category.

14 and frequently experienced poor acute clinical and functional outcomes.

Few prospective, observational studies of patients (either children or adults) with IVHs exist. Most previous studies are case reports or case series of both adults and children with IVHs. In a prospective, observational cohort study of adults and children with BHT, Atzema et al[10] described a 1.4% prevalence of IVH among those undergoing cranial CT. In that study, 7 (10%) of the patients were children. LeRoux et al[17] also described 43 patients with traumatic IVHs, but that was an older case series in which the prevalence was reported as 2.8% of those who underwent CT, and only 8 (19%) of the patients were children. In the present study, of the children undergoing cranial CT after BHT, the prevalence of IVH was the lowest reported of any study and was 21.4% of the prevalence that was described by Atzema et al.[10] However, this finding is not unexpected because our study included only children, in whom traumatic IVHs are rare, compared with adults and elderly patients. No lesions (eg, vascular malformations) were identified as an underlying cause of IVH in our cohort of children experiencing head trauma as may be expected in elderly patients.

Patients with IVHs often have serious sequelae. In adults, traumatic IVH is associated with a mortality rate of 22% to 62.5%.[13,18,19] Children with posttraumatic IVHs may experience equally serious outcomes, including death.[11,12,20] However, to our knowledge, no previous prospective, pediatric, observational cohort studies of traumatic IVH exist; therefore, the true prevalence and outcomes have been unknown. In one case series, 2 of 4 children with posttraumatic IVHs died, and 1 child was left in a persistent vegetative state after severe lateral impact.[11] Our experience was similar because more than 50% of children with nonisolated IVHs in the present study had severe disability or death.[10,17] In our series, more than 72.1% of children with nonisolated IVHs presented to the ED with GCS scores of 8 or lower. Clinical, pathologic, and radiologic studies of traumatic IVH implicate brainstem and other cerebral parenchymal contusion or hemorrhage as the source of ventricular system blood, and this finding would support the severe clinical presentations and adverse outcomes in children with IVHs and evidence of other ICIs on CT.[7,17,21]

The few reports of isolated IVH after head trauma in children demonstrate that children with isolated IVHs have different clinical findings and prognoses than those with IVHs in association with ICI on CT.[10,13] Similar to our findings, presenting GCS score and prognosis have been described to be related to the severity of the head trauma and presence of other ICIs on CT.[10,17,19] Atzema et al[10] reported that children and adults with isolated IVHs who appeared clinically well at ED presentation had good functional outcomes. In addition, IVH has been described as a low-risk CT finding in children and adults when no signs of clinical deterioration are present.[18,22] Isolated IVH may simply be secondary to vascular disruption localized to the ventricular system itself. Therefore, the degree of ICI may be limited, which is consistent with better clinical presentations and outcomes.

Our findings differ from previous investigations in several regards. To our knowledge, this is the only purely

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pediatric cohort study of IVH after BHT. Most existing reports[10,13,17,18] describe primarily adult patients with IVH and are mostly case series rather than cohort studies. The large study by Atzema et al[10] only contained 7 patients with IVH who were younger than 10 years of age.[23] Therefore, it is difficult to extrapolate the prevalence and outcomes of pediatric traumatic IVH from preexisting research studies. In other studies involving adults, poor outcome was associated with abnormal GCS scores at presentation, as well as with CT findings of deep-seated intraparenchymal hemorrhage and/or IVHs, which is similar to our findings with children.[12,24] In addition to specific CT findings, the mechanisms of injury and clinical symptoms of the patients in the present study were more varied compared with previous studies[11,12] that included predominantly patients with severe clinical presentations. Although 2 patients with isolated IVHs presented with substantially decreased levels of consciousness in another study, all the patients with isolated IVH in our study had GCS scores of 15.[12] This finding may also reflect the difference between case reports or case series rather than a large observational cohort such as that reported in our study. Furthermore, there were no deaths among the patients with isolated IVHs in our study, although of note, the 10 patients with isolated IVHs in our study had mechanisms of injury (motor vehicle related and falls) similar to those with nonisolated IVHs.

We also provide new information regarding functional outcomes of children with posttraumatic IVHs. Using the POPC and PCPC scores, we documented good functional outcome at hospital discharge of children with isolated IVHs and frequent poor functional outcome of those with IVHs in association with other ICIs on CT.

To our knowledge, this is the largest prospective cohort study to date describing children with IVHs after BHT. Our large sample size made it possible to separate children with isolated IVHs from those with nonisolated IVH and to demonstrate differences in functional outcomes between these 2 groups. Children with isolated IVHs appear to represent a distinct population compared with what is generally described in patients with traumatic IVHs. Children with isolated IVHs had normal GCS scores at presentation and had either normal functional outcomes or mild disability at hospital discharge. These data highlight that children with isolated IVHs have less severe outcomes than previously ascribed to the overall group of children with traumatic IVHs.

This study has several limitations. Most data were collected prospectively; however, to evaluate functional outcomes, we retrospectively reviewed medical records of children with IVH at the time of hospital discharge to obtain POPC and PCPC scores. It is possible that subtle functional abnormalities were missed and that functional status could worsen after hospital discharge. In addition, despite a large sample size in the parent study, there were only 53 children with IVHs, reflecting the infrequency of this finding and limiting the power to make statistical inferences when comparing those with isolated IVHs with those with nonisolated IVHs. However, these data represent the largest number of pediatric patients with posttraumatic IVHs studied in a prospective fashion to date. Finally, CT scans were interpreted by individual site faculty radiologists, and findings were not validated independently. Equivocal CT scans, however, were adjudicated by a senior faculty pediatric radiologist at the primary study site.

In conclusion, IVHs are uncommon in children after BHT. However, children with IVHs in association with other ICIs after BHT typically present with GCS scores of less than 14, frequently require neurosurgery, and often die or have functional disabilities at hospital discharge. In contrast, children with isolated IVHs typically present with normal GCS scores and have good clinical and functional outcomes. Therefore, children with isolated IVHs after BHT may be candidates for early hospital discharge or even extended ED observation for clinical signs of deterioration rather than definite hospital admission.

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Announcement

The *Archives of Pediatrics & Adolescent Medicine* will devote its May 2013 issue to pediatric hospital medicine. We are interested in a broad range of research related to hospital care, including clinical and comparative effectiveness research on the inpatient management of pediatric diseases. We invite all hospital-based pediatricians, including hospitalists, emergency medicine physicians, neonatologists, and intensivists to submit manuscripts, preferably by September 15, 2012.

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