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

Richard Lichenstein, MD; Todd F. Glass, MD, MS; Kimberly S. Quayle, MD; Sandra L. Wootton-Gorges, MD; David H. Wisner, MD; Michelle Miskin, MS; J. Paul Muizelaar, MD; Mohamed Badawy, MD; Shireen Atabaki, MD, MPH; James F. Holmes, MD, MPH; Nathan Kuppermann, MD, MPH; for the Traumatic Brain Injury Study Group of the Pediatric Emergency Care Applied Research Network (PECARN)

Objective: To describe the clinical presentations and outcomes of children with intraventricular hemor-

rhages (IVHs) after blunt head trauma (BHT).

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

Setting: Twenty-five emergency departments partici-
paring in the Pediatric Emergency Care Applied Re-
search 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 Cat-
egory (PCPC) scores at hospital discharge.

Results: Of 15,907 patients evaluated with computed to-
mography, 1156 (7.3%) had intracranial injuries. Forty-
three of the 1156 (3.7%; 95% CI, 2.7%-5.0%) had non-
isolated 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 re-
quired 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, how-
ever, 16 (37.2%) died and 18 (41.9%) required neuro-
surgery. In 27 patients (62.8%), injuries ranged from mod-
erate 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, fre-
quently require neurosurgery, and have high mortality
rates. In contrast, those with isolated IVHs typically pre-

Author Affiliations are listed at
the end of this article.
diagnostic 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.\textsuperscript{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.\textsuperscript{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.

**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, subdural hematoma, subarachnoid hemorrhage, hydrocephalus, and depressed skull fracture at least the width of the table of the skull.

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.\textsuperscript{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).\textsuperscript{3,16}

**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.
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 8.5.
at et al.10 However, this finding is not unexpected because
21.4% of the prevalence that was described by Atzema
of IVH was the lowest reported of any study and was
patients were children. In the present study, of the chil-
series in which the prevalence was reported as 2.8% of
patients with traumatic IVHs, but that was an older case
study included only children, in whom traumatic
IVH exist; therefore, the true prevalence and out-
comes have been unknown. In one case series, 2 of 4
children with postrumatic IVHs died, and 1 child was
left in a persistent vegetative state after severe lateral im-
pact.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 brain-
stem and other cerebral parenchymal contusion or hem-
orrhage as the source of ventricular system blood, and
this finding would support the severe clinical presenta-
tions 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.10,17,20 Atzema
et al10 reported that children and adults with isolated IVHs
who appeared clinically well at ED presentation had good
functional outcomes. In addition, IVH has been de-
scribed as a low-risk CT finding in children and adults
when no signs of clinical deterioration are present.10,22
Isolated IVH may simply be secondary to vascular dis-
ruption localized to the ventricular system itself. There-
fore, the degree of ICI may be limited, which is consis-
tent with better clinical presentations and outcomes.

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

<table>
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<tr>
<th>Table 2. Comparison of Radiographic Findings Between Patients With Nonisolated and Isolated IVHs on Computed Tomography</th>
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<tr>
<td>Finding</td>
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<tr>
<td>---------------------------------------------------------------</td>
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<tr>
<td>IVH location</td>
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<tr>
<td>Lateral ventricles only</td>
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<td>Third or fourth ventricles or cerebral aqueduct only</td>
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<td>Both ventricular areas</td>
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<td>Intracranial injuries</td>
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<tr>
<td>Cerebellar hemorrhage</td>
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<td>Cerebral contusion</td>
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<td>Cerebral edema</td>
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<td>Cerebral hemorrhage or intracerebral hematoma</td>
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<td>Diastasis of the skull</td>
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<td>Epidural hematoma</td>
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<td>Extra-axial hematoma</td>
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<tr>
<td>Midline shift</td>
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<td>Pneumocephalus</td>
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<td>Subarachnoid hemorrhage</td>
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<td>Subdural hematoma</td>
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<td>Diffuse axonal injury</td>
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<td>Herniation</td>
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<td>Shear injury</td>
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Abbreviation: IVH, intraventricular hemorrhage.

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<tr>
<th>Table 3. Comparison of Clinical and Functional Outcomes Between Patients With Nonisolated and Isolated IVHs on Computed Tomography</th>
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<tr>
<td>Outcome</td>
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<td>---------------------------------------------------------------</td>
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<tr>
<td>Acute adverse and functional outcomes</td>
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<tr>
<td>Death</td>
</tr>
<tr>
<td>Neurosurgery</td>
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<tr>
<td>Intubated for &gt;24 h for ICI</td>
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<tr>
<td>PDPC score at ED or hospital discharge</td>
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<tr>
<td>Good overall performance</td>
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<tr>
<td>Mild overall disability</td>
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<tr>
<td>Moderate overall disability</td>
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<td>Severe overall disability</td>
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<tr>
<td>Brain death</td>
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<tr>
<td>PCPC score at ED or hospital discharge</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Mild disability</td>
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<tr>
<td>Moderate disability</td>
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<td>Severe disability</td>
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<td>Brain death</td>
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Abbreviations: ED, emergency department; ICI, intracranial injury; IVH, intraventricular hemorrhage; PCPC, Pediatric Cerebral Performance Category; PDPC, 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 al10 described a 1.4% prevalence of IVH among those
undergoing cranial CT. In this study, 7 (10%) of the
patients were children. LeRoux et al17 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 chil-
ren 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 postrumatic IVHs may experience equally serious outcomes, including death.11,12,20 However, to our knowledge, no previous pro-
spective, pediatric, observational cohort studies of traum-
atic IVH exist; therefore, the true prevalence and out-
comes
pediatric cohort study of IVH after BHT. Most existing reports describe primarily adult patients with IVH and are mostly case series rather than cohort studies. The large study by Atzema et al only contained 7 patients with IVH who were younger than 10 years of age. 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. 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 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. 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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Author Affiliations: Department of Pediatrics, University of Maryland School of Medicine, Baltimore (Dr Lichenstein); Department of Pediatric Emergency Medicine, University of Cincinnati College of Medicine, Cincinnati, Ohio (Dr Glass); Department of Pediatrics, Washington University School of Medicine, St Louis, Missouri (Dr Quayle); Departments of Radiology (Dr Wootton-Gorges), Surgery (Dr Wisner), Neurological Surgery (Dr Muizelaar), Emergency Medicine (Drs Holmes and Kuppermann), and Pediatrics (Dr Kuppermann), University of California–Davis School of Medicine, Davis; Department of Pediatrics, University of Utah, Salt Lake City (Ms Miskin); Department of Emergency Medicine, University of Rochester School of Medicine, Rochester, New York (Dr Badawy); and Department of Pediatrics, George Washington School of Medicine, Washington, DC (Dr Atabaki). A complete list of the individuals participating in PECARN at the time this study was initiated appears at the end of this article.

Correspondence: Richard Lichenstein, MD, Department of Pediatrics, University of Maryland School of Medicine, 22 S Greene St, Baltimore, MD 21201 (rlichenstein@peds.umaryland.edu).


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†Deceased.

REFERENCES


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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.