The Prevalence of Traumatic Brain Injuries After Minor Blunt Head Trauma in Children With Ventricular Shunts

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Study objective: We compare the prevalence of clinically important traumatic brain injuries and the use of cranial computed tomography (CT) in children with minor blunt head trauma with and without ventricular shunts.

Methods: We performed a secondary analysis of a prospective observational cohort study of children with blunt head trauma presenting to a participating Pediatric Emergency Care Applied Research Network emergency department. For children with Glasgow Coma Scale (GCS) scores greater than or equal to 14, we compared the rates of clinically important traumatic brain injuries (defined as a traumatic brain injury resulting in death, neurosurgical intervention, intubation for more than 24 hours, or hospital admission for at least 2 nights for management of traumatic brain injury in association with positive CT scan) and use of cranial CT for children with and without ventricular shunts.

Results: Of the 39,732 children with blunt head trauma and GCS scores greater than or equal to 14, we identified 98 (0.2%) children with ventricular shunts. Children with ventricular shunts had more frequent CT use: (45/98 [46%] with shunts versus 13,858/39,634 [35%] without; difference 11%; 95% confidence interval 1% to 21%) but a similar rate of clinically important traumatic brain injuries (1/98 [1%] with shunts versus 346/39,619 [0.9%] without; difference 0.1%; 95% confidence interval −0.3% to 5%). The one child with a ventricular shunt who had a clinically important traumatic brain injury had a known chronic subdural hematoma that was larger after the head trauma compared with previous CT; the child underwent hematoma evacuation.

Conclusion: Children with ventricular shunts had higher CT use with similar rates of clinically important traumatic brain injuries after minor blunt head trauma compared with children without ventricular shunts. [Ann Emerg Med. 2013;61:389-393.]

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INTRODUCTION

In the United States, approximately 1 in 500 children has a ventricular shunt to drain excess or obstructed cerebrospinal fluid.[1,2] It is not known whether the presence of a ventricular shunt increases the risk of traumatic brain injury after blunt head trauma and therefore whether thresholds for obtaining cranial computed tomography (CT) scans after blunt head trauma should be different than for other children.

Previous investigators suggested that an association exists between ventricular shunts and risk of traumatic brain injury.[3-5] A ventricular shunt stretches the bridging veins or cortical arteries that normally adhere to the inner surface of the dura, potentially risking intracranial hemorrhage after minor blunt head trauma.[6] Three small retrospective series describe some patients with ventricular shunts and intracranial hemorrhages after blunt head trauma.[4-6] All children described in these series presented with signs or symptoms suggestive of traumatic brain injury. However, to our knowledge no large prospective cohort of children with ventricular shunts and blunt head trauma exists to precisely assess the risk of traumatic brain injury and to determine whether the risk differs from that of children without ventricular shunts. Because children with ventricular shunts are already exposed to repeated CT scans,[7] avoiding additional ionizing radiation exposure would be beneficial.

The Pediatric Emergency Care Applied Research Network (PECARN) previously conducted a prospective observational

*Participating centers and site investigators are listed in the Appendix.

Editor's Capsule Summary

What is already known on this topic

Previous case reports suggest increased risk of traumatic brain injury in children with ventricular shunts who sustain head trauma.

What question this study addressed

This study measured the prevalence of clinically important traumatic brain injuries in a cohort of head-injured children younger than 18 years with and without ventricular shunt.

What this study adds to our knowledge

Children with ventricular shunts had a rate of clinically important traumatic brain injuries (1/98; 1%) similar to that of those without (346/39,619; 0.9%) but higher rate of cranial computed tomography (CT) use (45/98 versus 13,858/39,634; 46% versus 35%).

How this is relevant to clinical practice

Routine cranial CT may not be indicated in head-injured children with ventricular shunts in the absence of other risk factors for traumatic brain injury.

study of more than 40,000 children with blunt head trauma. In this planned secondary analysis, we explored the relationship between the presence of a ventricular shunt and the risk of traumatic brain injury.

MATERIALS AND METHODS

Study Design

We conducted an a priori planned secondary analysis of children who were enrolled in a large prospective cohort study of children younger than 18 years and with blunt head trauma. Study patients presented to one of 25 emergency departments (EDs) participating in the PECARN (2004 to 2006). The study protocol was approved by the institutional review board at each participating site, with waiver of consent at some sites and verbal consent for telephone follow-up at others. Details of study methods have been described previously.[8]

Selection of Participants

Children presenting within 24 hours after blunt head trauma after nontrivial injury mechanisms were included. Patients with known brain tumors, preexisting neurologic disorders, bleeding disorders, or neuroimaging performed at a transferring hospital were excluded from the parent study and this substudy. We excluded from this substudy children with missing clinical data about the presence of a ventricular shunt. For this substudy, we focused on those with Glasgow Coma Scale (GCS) scores of 14 to 15 at initial ED presentation because these are the patients for whom the greatest controversy exists about the role of CT scans.

Data Collection and Processing

The treating emergency physician completed a standardized study data collection form at the ED visit, which included patient history, injury mechanism, symptoms, and signs. Clinicians were asked to indicate the presence or absence of a ventricular shunt.

Outcome Measures

Our primary outcome measures were the prevalence of clinically important traumatic brain injury and traumatic brain injury on cranial CT scan; our secondary outcome measure was the rate of CT use. Cranial CT scans were performed at the clinician's discretion and were interpreted by study site faculty radiologists, with external review for inconclusive cases. Children who were discharged from the ED without a cranial CT scan had clinical telephone follow-up by trained research staff between 1 week and 3 months from the initial ED visit.[8] We defined clinically important traumatic brain injury by the presence of one or more of the following: a traumatic brain injury resulting in death, neurosurgical intervention, intubation for greater than 24 hours, or 2 or more nights in the hospital for the management of the traumatic brain injury in association with a positive CT scan result. We defined a positive CT scan result as any of the following: intracranial hemorrhage or contusion, traumatic infarction, sigmoid sinus thrombosis, diffuse axonal injury, pneumocephalus, midline shift or signs of brain herniation, diastasis of the skull, or skull fracture depressed more than the table width of the skull.

Primary Data Analysis

We described the data by using descriptive statistics with 95% confidence intervals (CIs), where appropriate. We first performed a bivariable analysis comparing demographic and injury severity characteristics of children with initial GCS scores greater than or equal to 14 with and without ventricular shunts. We then compared rates of cranial CT use, positive CT results, and clinically important traumatic brain injuries for children with and without ventricular shunts. We used the Newcombe-Wilson continuity adjusted method because of low prevalence rates.[9] Finally, we performed multivariable logistic regression with generalized estimating equations to compare CT rates between patients with and without ventricular shunts. The generalized estimating equation models adjusted for clinical severity and for clustering of CT use by hospitals.

We performed the data analysis with SAS software (version 9.2; SAS Institute, Inc., Cary, NC).

RESULTS

Of the 57,030 eligible patients, 43,498 (76%) were enrolled in the parent study of blunt head trauma. We excluded 2,912

Table 1. Patient characteristics of children with minor blunt head trauma, with initial GCS scores greater than or equal to 14, and with and without a ventricular shunt present.

Clinical Variables	Ventricular Shunt Present (%) (N=98)	No Ventricular Shunt Present (%) (N=39,634)	% Difference (95% CI)
Age <2 y	19/98 (19)	9,983/39,634 (25)	−6 (−12 to 3)
Altered mental status*	14/98 (14)	5,126/39,380 (13)	1 (−4 to 10)
History of vomiting	15/94 (16)	5,192/39,403 (13)	3 (−3 to 12)
Severe injury mechanism†	10/97 (10)	5,479/39,351 (14)	−4 (−8 to 4)
History of loss of consciousness	8/94 (9)	5,885/38,054 (15)	−6 (−11 to 0.6)
History of seizure	1/95 (1)	460/39,008 (1)	0 (−0.6 to 5)
Clinical evidence of skull fracture‡	1/97 (1)	1,200/39,232 (3)	−2 (−3 to 3)
Nonfrontal scalp hematoma	18/96 (19)	7,280/39,220 (19)	0 (−6 to 9)

*GCS score of 14, agitation, sleepiness, slow responses, or repetitive questioning.
†Motor vehicle collision with patient ejection, death of another passenger or rollover, a pedestrian or bicyclist without helmet who is struck by a motorized vehicle, falls (height >3 feet for children <2 years and >5 feet for children ≥2 years), or head struck with high-impact object.
‡Probable or possible skull fracture according to palpation of skull fracture, or unclear because of swelling or distortion of the scalp on digital examination, or signs of basilar skull fracture.

Table 2. Comparison of rates of clinically important traumatic brain injuries, positive CT scan results, and cranial CT scan rates between patients with and without ventricular shunts.

	Ventricular Shunts (%) (N=98)	No Ventricular Shunts (%) (N=39,634)	% Difference (95% CI)
Clinically important traumatic brain injury	1/98 (1)	346/39,619 (0.9)	0.1 (−0.3 to 5)
Positive CT scan result	1/45 (2)	713/13,634 (5)	3 (−4 to 7)
Cranial CT rate	45/98 (46)	13,858/39,634 (35)	11 (1 to 21)

children for missing information about the presence or absence of ventricular shunts. Of the resulting 40,586 patients, 39,732 children had initial GCS scores greater than or equal to 14, including 98, or 0.2%, with ventricular shunts, and serve as the population analyzed.

Study patients with and without ventricular shunts were similar with regard to baseline clinical characteristics (Table 1). The rate of cranial CT scan use was higher in children with ventricular shunts than those without ventricular shunts, although the rates of clinically important traumatic brain injuries and of positive CT scan results were similar (Table 2). The CT rate difference corresponds to a number needed to harm (assuming that the "harm" is defined by excess CT use) of 1 additional CT per 9 children with ventricular shunts compared with those without ventricular shunts (95% CI 5 to 100 children). The one patient with a ventricular shunt and a clinically important traumatic brain injury was a 10-year-old boy who walked into a stationary object (a minor injury mechanism) and had no PECARN traumatic brain injury predictors (Table 3).[8] However, this patient had a preexisting subdural hematoma, which was found to have expanded slightly after the minor head trauma (compared to previous CTs), leading to neurosurgical drainage.

After adjusting for clinical severity and hospital center, children with ventricular shunts remained more likely to have cranial CT scans performed (adjusted odds ratio 2.1; 95% CI 1.3 to 3.5).

Table 3. Clinical predictors included in the PECARN traumatic brain injury clinical prediction rules for children younger than 2 years or 2 years and older.[8]

Younger Than 2 Years	2 Years or Older
Altered mental status*	Altered mental status*
Severe injury mechanism†	Severe injury mechanism†
Palpable or unclear skull fracture	Signs of basilar skull fracture‡
Loss of consciousness for ≥5 s	Any loss of consciousness
Nonfrontal scalp hematoma	History of vomiting
Not acting normally per parents	Severe headache

*GCS score ≥14, agitation, sleepiness, slow response, or repetitive questioning.
†Motor vehicle crash with patient ejection, death of another passenger or rollover, pedestrian or bicyclist without helmet who is struck by motorized vehicle, falls (of >3 feet for children <2 years or >5 feet for children ≥2 years), or head struck by high-impact object.
‡Retroauricular bruising (battle sign), periorbital bruising (raccoon eyes), cerebrospinal fluid otorrhea or hemotympanum.

LIMITATIONS

Our study had some limitations. First, although this was a very large prospective cohort study, we had a relatively small number of children with ventricular shunts, limiting our ability to make precise risk estimates. Therefore, we cannot exclude the possibility that we failed to detect a difference in traumatic brain injury rates between patients with and without ventricular shunts. Nevertheless, the CIs around the differences between groups were relatively narrow, even after use of accepted statistical methods for rare outcomes.

Second, study patients had CT scans performed at the discretion of the treating clinicians. Children who did not have CT scans performed, however, had standardized clinical follow-up, making a missed clinically important traumatic brain injury very unlikely.

Third, the radiologists who interpreted the CT scans were not blinded to clinical information; however, they were unaware of the conduct and purpose of this substudy.

Fourth, we consider the possibility that children with ventricular shunts may not be allowed or able to participate in all of the activities that children without ventricular shunts do. Thus, they may have less intense head trauma, coupled with a lower threshold to come to the ED for evaluation compared with children without shunts. The equivalence in the observed rates of clinically important traumatic brain injuries and positive CT results might then be due to a combination of a higher propensity for brain injury and a lower intensity of injury.

Fifth, although the similar clinical predictors of head injury severity for children with and without ventricular shunts might suggest that there were no differences in injury severity (Table 1), the study was not powered for this comparison and confounding may have occurred.

Finally, 7% of study patients were excluded because of incomplete or missing information about the presence of ventricular shunts on their case report forms. Patients without such documentation were very unlikely to have ventricular shunts, given that the prevalence of children with ventricular shunts in the overall enrolled population was just 0.2%. Therefore, it is unlikely that this would affect the results of the analysis.

DISCUSSION

In this large prospective cohort of children with minor blunt head trauma, the prevalence of clinically important traumatic brain injuries, as well as positive CT scan results, in children with ventricular shunts was similar to that of children with minor blunt head trauma without ventricular shunts. However, we observed higher CT scan use in the children with ventricular shunts, both in bivariable analysis and in multivariable analysis adjusting for signs and symptoms associated with traumatic brain injury.

Children with ventricular shunts need careful evaluation by trained clinicians after blunt head trauma, as do all children regardless of the presence of a ventricular shunt. Although the one child with a ventricular shunt and a clinically important traumatic brain injury had no PECARN traumatic brain injury predictors,[8] that child had a preexisting subdural hematoma, which would have alerted the treating clinician to the increased risk in this case. Clinical prediction rules for traumatic brain injury should not be applied to children with preexisting intracranial hemorrhages. It is possible that the increase in subdural blood in this patient was present before the minor traumatic event but was brought to attention by the performance of the CT.

Because it appears that the risk of clinically important traumatic brain injuries is not higher in children with ventricular shunts compared with those without such shunts, clinicians should not base neuroimaging decisions after minor blunt head trauma purely on the presence of a ventricular shunt. Given these findings, it is possible that the PECARN traumatic brain injury prediction rules[8] apply to such children with ventricular shunts, although it is difficult to make this conclusion with great precision, given the limited number of children with shunts who were enrolled in the study.

In children with ventricular shunts, the prevalence of clinically important traumatic brain injuries was similar to that of children without ventricular shunts. Our findings suggest that routine neuroimaging for children with ventricular shunts after minor blunt head trauma may not be required in the absence of signs and symptoms of traumatic brain injury.

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APPENDIX

Participating centers and site investigators are listed below in alphabetical order: Atlantic Health System/Morristown Memorial Hospital (M. Gerardi); Bellevue Hospital Center (M. Tunik, J. Tsung); Calvert Memorial Hospital (K. Melville); Boston Children's Hospital (L. Lee); Women and Children's Hospital of Buffalo (K. Lillis); Children's Hospital of Michigan (P. Mahajan); Children's Hospital of New York–Presbyterian (P. Dayan); Children's Hospital of Philadelphia (F. Nadel); Children's Memorial Hospital (E. Powell); Children's National Medical Center (S. Atabaki, K. Brown); Cincinnati Children's Hospital Medical Center (T. Glass); DeVos Children's Hospital (J. Hoyle); Harlem Hospital Center (A. Cooper); Holy Cross Hospital (E. Jacobs); Howard County Medical Center (D. Monroe); Hurley Medical Center (D. Borgialli); Medical College of Wisconsin/Children's Hospital of Wisconsin (M. Gorelick, S. Bandyopadhyay); St. Barnabas Health Care System (M. Bachman, N. Schamban); SUNY–Upstate Medical University (J. Callahan); University of California Davis Medical Center (N. Kuppermann, J. Holmes); University of Maryland (R. Lichenstein); University of Michigan (R. Stanley); University of Rochester (M. Badawy, L. Babcock-Cimpello); University of Utah/Primary Children's Medical Center (J. Schunk); Washington University/St. Louis Children's Hospital (K. Quayle, D. Jaffe).