Vomiting With Head Trauma and Risk of Traumatic Brain Injury

Meredith L. Borland, MBBS,[a,b] Stuart R. Dalziel, PhD,[c,d] Natalie Phillips, MBBS,[e,f] Sarah Dalton, BMed,[g] Mark D. Lyttle, MBChB,[h,i,j] Silvia Bressan, PhD,[h,k] Ed Oakley, MBBS,[h,l,m] Stephen J.C. Hearps, PGDipBiostat,[h] Amit Kochar, MD,[n] Jeremy Furyk, MBBS,[o] John A. Cheek, MBBS,[h,l] Jocelyn Neutze, MBChB,[p] Franz E. Babl, MD,[h,l,m] on behalf of the Paediatric Research in Emergency Department International Collaborative group

abstract

OBJECTIVES: To determine the prevalence of traumatic brain injuries in children who vomit after head injury and identify variables from published clinical decision rules (CDRs) that predict increased risk.

METHODS: Secondary analysis of the Australasian Paediatric Head Injury Rule Study. Vomiting characteristics were assessed and correlated with CDR predictors and the presence of clinically important traumatic brain injury (ciTBI) or traumatic brain injury on computed tomography (TBI-CT). Isolated vomiting was defined as vomiting without other CDR predictors.

RESULTS: Of the 19 920 children enrolled, 3389 (17.0%) had any vomiting, with 2446 (72.2%) >2 years of age. In 172 patients with ciTBI, 76 had vomiting (44.2%; 95% confidence interval [CI] 36.9%–51.7%), and in 285 with TBI-CT, 123 had vomiting (43.2%; 95% CI 37.5%–49.0%). With isolated vomiting, only 1 (0.3%; 95% CI 0.0%–0.9%) had ciTBI and 2 (0.6%; 95% CI 0.0%–1.4%) had TBI-CT. Predictors of increased risk of ciTBI with vomiting by using multivariate regression were as follows: signs of skull fracture (odds ratio [OR] 80.1; 95% CI 43.4–148.0), altered mental status (OR 2.4; 95% CI 1.0–5.5), headache (OR 2.3; 95% CI 1.3–4.1), and acting abnormally (OR 1.86; 95% CI 1.0–3.4). Additional features predicting TBI-CT were as follows: skull fracture (OR 112.96; 95% CI 66.76–191.14), nonaccidental injury concern (OR 6.75; 95% CI 1.54–29.69), headache (OR 2.55; 95% CI 1.52–4.27), and acting abnormally (OR 1.83; 95% CI 1.10–3.06).

CONCLUSIONS: TBI-CT and ciTBI are uncommon in children presenting with head injury with isolated vomiting, and a management strategy of observation without immediate computed tomography appears appropriate.

[a]*Princess Margaret Hospital for Children, Perth, Australia;* [b]*Division of Paediatrics and Emergency Medicine, School of Medicine, University of Western Australia, Crawley, Australia;* [c]*Starship Children's Health, Auckland, New Zealand;* [d]*Liggins Institute, University of Auckland, Auckland, New Zealand;* [e]*Lady Cilento Children's Hospital, South Brisbane, Australia;* [f]*Child Health Research Centre, School of Medicine, The University of Queensland, Brisbane, Australia;* [g]*The Children's Hospital at Westmead, Sydney, Australia;* [h]*Murdoch Children's Research Institute, Melbourne, Australia;* [i]*Bristol Royal Hospital for Children, Bristol, United Kingdom;* [j]*Academic Department of Emergency Care, University of the West of England, Bristol, Bristol, United Kingdom;* [k]*Department of Women's and Children's Health, University of Padova, Padova, Italy;* [l]*The Royal Children's Hospital, Melbourne, Australia;* [m]*Department of Paediatrics, Faculty of Medicine, Dentistry, and Health Sciences, University of Melbourne, Melbourne, Australia;* [n]*Women's and Children's Hospital, North Adelaide, Australia;* [o]*The Townsville Hospital, Townsville, Australia; and* [p]*Kidz First Children's Hospital, Auckland, New Zealand*

A complete list of non-author contributors appears in the Supplemental Information.

Dr Borland conceptualized and contributed to the data collection for the original study, conceptualized this study, interpreted the data for this study, drafted the initial manuscript, and revised the manuscript; Dr Babl conceptualized and devised the data collection tools, contributed to collection, coordinated and supervised data collection for the original study, and reviewed and

WHAT'S KNOWN ON THIS SUBJECT: Vomiting episodes in children with head injury have been assumed to indicate more severe injury and as such are often an indication to undergo cranial computed tomography to exclude clinically important traumatic brain injury.

WHAT THIS STUDY ADDS: In this study, we have confirmed that isolated vomiting is rarely associated with significant traumatic brain injury and has delineated coexisting factors, which are associated with an increased risk of clinically important traumatic brain injury.

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TABLE 1 Outcome Definitions

ciTBI Outcomes	TBI-CT Outcomes
Death	Intracranial hemorrhage or contusion
Intubation for >24 h	Cerebral edema
Neurosurgery	Traumatic infarction
Hospital admission of ≥2 nights	Diffuse axonal injury
	Shearing injury
	Sigmoid sinus thrombosis
	Intracranial contents or signs of brain herniation
	Midline shift
	Diastasis of the skull
	Pneumocephalus
	Depressed skull fracture

Retrieved from Dayan PS, Holmes JF, Atabaki S, et al; Traumatic Brain Injury Study Group of the Pediatric Emergency Care Applied Research Network. Association of traumatic brain injuries with vomiting in children with blunt head trauma. *Ann Emerg Med.* 2014;63(6):657–665.

Mild-to-moderate blunt head injuries in children are a common reason for presentation to emergency departments (EDs) worldwide.[1–3] These injuries cause considerable decision-making dilemmas because clinicians balance the need to undertake a computed tomography (CT) scan to look for clinically important traumatic brain injury (ciTBI) against the risks of exposing the developing brain to ionizing radiation.[4–6] Vomiting has been associated with an increased risk of more severe head injury and as such is often an indication to undergo cranial CT.[1,4,7,8] The prevalence of ciTBI in children who sustain head injury[9–12] has been described in studies to derive clinical decision rules (CDRs), which guide the use of cranial CT scanning in these children. Both the Pediatric Emergency Care Applied Research Network (PECARN)[10] and the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE)[9] CDRs included vomiting episodes as a predictor variable; however, researchers in these studies used different cutoffs for frequency of vomiting.[13] CHALICE, which is the most liberal with the numbers of vomits (≥3 episodes) before triggering a CT scan, has been criticized because the positive predictive value (PPV) of an abnormal CT result in children with isolated vomiting remains low at 3.7% in pediatric patients.[14] The PECARN CDR includes the presence of any vomiting as a predictor variable in children aged ≥2 years, although it suggests that when isolated, this may carry only intermediate risk, and so observation may be appropriate rather than immediate CT scanning. Researchers who conducted a secondary analysis of the PECARN study[15] have also confirmed that ciTBI is uncommon in the presence of isolated vomiting. After the publication of the CHALICE CDR the National Institute for Health and Clinical Excellence recommended that CT scanning be done in children with head injury and ≥3 episodes of vomiting[16]; this was modified in the most recent iteration that if there were no other features, these children may be observed.

We undertook a prospective observational study to compare 3 high-quality CDRs (the PECARN, CHALICE, and Canadian Assessment of Tomography for Childhood Head Injury [CATCH])[9–11] that guide the use of CT in pediatric head injuries, externally validating the CDRs in a population outside their derivation sites.[17] In this planned secondary analysis of our cohort, we aim to determine the prevalence of ciTBI in children with vomiting and the relationship between age, frequency of vomiting, mechanism of injury, and ciTBI. We also sought to determine which PECARN and CHALICE CDR predictors, when present with vomiting, increase the risk of either ciTBI or the wider clinical group of traumatic brain injury on computed tomography (TBI-CT). Because the CATCH CDR included vomiting as part of the composite definition of mild TBI, we did not include its predictor variables as a direct comparator in our cohort.

METHODS

Study Design, Setting, and Patients

This was a planned secondary analysis of the Australasian Paediatric Head Injury Rule Study (APHIRST)[18] of children <18 years old with head injury presenting between April 2011 and November 2014 to 10 pediatric EDs in Australia and New Zealand associated with the Paediatric Research in Emergency Departments International Collaborative research network.[19] We collected all published rule-specific predictor and outcome variables for the PECARN, CATCH, and CHALICE CDRs. Patients with the following were excluded: trivial facial injury only, patient and/or family refusal to participate, referral from ED triage to an external provider (ie, not seen in the ED), neuroimaging done before the transfer to a study site, and those who did not wait to be seen.

In this planned subanalysis, we assessed the history and characteristics of vomiting at the initial evaluation in the ED. We correlated the presence of vomiting with the mechanism of injury, age of the patient, and presence of both ciTBI and TBI-CT as defined in the PECARN study (Table 1).[10] We analyzed separately children <2 and ≥2 years old because the PECARN CDR did not include vomiting for children <2 years old. We also correlated the presence of vomiting with high-risk mechanisms as defined by the CHALICE of high-speed road traffic crash either as pedestrian, cyclist, or occupant (speed >40

TABLE 2 Mechanism of Injury in Children Who Vomit

	No Vomiting			Any Vomiting			1 Vomit			2 Vomits			≥3 Vomits			*P*
	n	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	
All ages, y	16 531	83.0	(82.5–83.5)	3389	17.0	(16.5–17.5)	1305	6.6	(6.2–6.9)	843	4.2	(4.0–4.5)	1241	6.2	(5.9–6.6)	
<1	1847	11.2	(10.7–11.7)	471	13.9	(12.7–15.1)	223	17.1	(15.1–19.1)	121	14.4	(12.0–16.7)	127	10.2	(8.6–11.9)	<.001
1–2	2545	15.4	(14.9–16.0)	472	13.9	(12.8–15.1)	191	14.6	(12.7–16.6)	103	12.2	(10.0–14.4)	178	14.3	(12.4–16.3)	—
>2	12 139	73.4	(72.8–74.1)	2446	72.2	(70.7–73.7)	891	68.3	(65.8–70.8)	619	73.4	(70.4–76.4)	936	75.4	(73.0–77.8)	—
Sex																
Female	5835	35.3	(34.6–36.0)	1398	41.3	(39.6–42.9)	547	41.9	(39.2–44.6)	344	40.9	(37.5–44.2)	507	40.9	(38.1–43.6)	<.001
Mechanism																
Falls	11 385	70.6	(69.9–71.3)	2628	78.8	(77.4–80.2)	977	76.6	(74.3–79.0)	669	80.2	(77.5–82.9)	982	80.0	(77.8–82.3)	<.001
From height <3 ft	8171	50.7	(49.9–51.4)	1677	50.3	(48.6–52.0)	652	51.1	(48.4–53.9)	415	49.8	(46.4–53.2)	610	49.7	(46.9–52.5)	<.001
From height 3–5 ft	2042	12.7	(12.2–13.2)	621	18.6	(17.3–19.9)	219	17.2	(15.1–19.3)	158	18.9	(16.3–21.6)	244	19.9	(17.7–22.1)	—
From height 6–10 ft	848	5.3	(4.9–5.6)	247	7.4	(6.5–8.3)	79	6.2	(4.9–7.5)	66	7.9	(6.1–9.8)	102	8.3	(6.8–9.9)	—
From height >10 ft	121	0.8	(0.6–0.9)	25	0.8	(0.5–1.0)	8	0.6	(0.2–1.1)	10	1.2	(0.5–1.9)	7	0.6	(0.2–1.0)	—
Unknown height	203	1.3	(1.1–1.4)	58	1.7	(1.3–2.2)	19	1.5	(0.8–2.2)	20	2.4	(1.4–3.4)	19	1.6	(0.9–2.2)	—
Fall downstairs	218	1.4	(1.2–1.6)	39	1.2	(0.8–1.6)	16	1.3	(0.7–1.9)	10	1.2	(0.5–2.0)	13	1.1	(0.5–1.7)	.398
Traffic incident																
Pedestrian struck by moving vehicle	177	1.1	(0.9–1.3)	30	0.9	(0.6–1.2)	15	1.2	(0.6–1.8)	7	0.8	(0.2–1.5)	8	0.7	(0.2–1.1)	.305
Bike rider struck by automobile	21	0.1	(0.1–0.2)	2	0.1	(0.0–0.1)	2	0.2	(0.0–0.4)	0	0.0	(0.0–0.0)	0	0.0	(0.0–0.0)	.281
Fall from bicycle (no helmet)	287	1.8	(1.6–2.0)	88	2.6	(2.1–3.2)	33	2.6	(1.7–3.4)	23	2.7	(1.6–3.9)	32	2.6	(1.7–3.5)	.001
Motor vehicle–related	643	4.0	(3.7–4.3)	125	3.7	(3.1–4.4)	63	4.9	(3.7–6.1)	27	3.2	(2.0–4.4)	35	2.8	(1.9–3.7)	.504
Miscellaneous																
Object struck head, unintended	1132	7.0	(6.6–7.4)	160	4.8	(4.1–5.5)	76	5.9	(4.6–7.2)	25	3.0	(1.8–4.2)	59	4.8	(3.6–6.0)	<.001
Assault (NAI concern)	78	0.5	(0.4–0.6)	23	0.7	(0.4–1.0)	7	0.5	(0.1–0.9)	8	1.0	(0.3–1.6)	8	0.6	(0.2–1.1)	.168

—, not applicable.

miles per hour); falling from >3 m in height; or a high-speed injury from a projectile or other object.

To overcome difficulties in comparing the CDRs with different inclusion and exclusion criteria (including age, Glasgow Coma Score [GCS], and rule-specific outcomes), we created a homogeneous comparison cohort for secondary analyses. This cohort included all children (<18 years old) who presented within 24 hours with minor head injury (defined as GCS scores of 13–15 on ED presentation). We report the relationship in our vomiting cohort to the prediction rule variables for the 2 CDRs, namely loss of consciousness (LOC), headache, acting abnormally according to parents in children <2 years old, amnesia, seizure, nonaccidental injury (NAI) concern, altered mental state, examination features suggestive of skull fracture, abnormal GCS, neurologic deficit, and a scalp hematoma. We then determined the relationship of these variables with the number of vomiting episodes (1, 2, or ≥3 times) and specifically compared the prediction variables in children <2 and ≥2 years old. We subsequently performed a multivariate logistic regression analysis to assess the independent associations of head injury signs and symptoms with the presence of ciTBI and TBI-CT in children with vomiting.

The institutional ethics committees at each participating site approved the study. We obtained informed verbal consent from parents and/or guardians, apart from instances of significant life-threatening or fatal injuries, when participating ethics committees granted a waiver of consent.

The trial protocol[17] was developed by the study investigators and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12614000463673).

TABLE 3 Vomiting and ciTBI and TBI-CT by CDR Predictor Variables

	Total (With and Without Other CDR Predictors)						No Other CDR Rule Predictors					
	No ciTBI			ciTBI			No ciTBI			ciTBI		
	n	%	95% CI	*n*	%	95% CI	*n*	%	95% CI	*n*	%	95% CI
Vomiting and ciTBI by CDR predictor variables												
No vomiting	16 435	83.2	(82.7–83.7)	96	55.8	(48.3–63.1)	7452	88.1	(87.4–88.8)	1	50.0	(1.9–98.1)
Any vomiting	3313	16.8	(16.3–17.3)	76	44.2	(36.9–51.7)	1005	11.9	(11.2–12.6)	1	50.0	(1.9–98.1)
No. vomits												
1	1284	6.5	(6.2–6.9)	21	12.2	(8.1–18.0)	412	4.9	(4.4–5.4)	0	0.0	—
2	818	4.1	(3.9–4.4)	25	14.5	(10.0–20.6)	250	3.0	(2.6–3.3)	0	0.0	—
≥3	1211	6.1	(5.8–6.5)	30	17.4	(12.5–23.9)	343	4.1	(3.7–4.5)	1	50.0	(1.9–98.1)
Vomiting and TBI-CT[a], by CDR predictor variables												
No vomiting	16 369	83.4	(82.8–83.9)	162	56.8	(51.0–62.5)	7452	88.1	(87.4–88.8)	1	33.3	(2.6–90.4)
Any vomiting	3266	16.6	(16.1–17.2)	123	43.2	(37.5–49.0)	1004	11.9	(11.2–12.6)	2	66.7	(9.6–97.4)
No. vomits												
1	1269	6.5	(6.1–6.8)	36	12.6	(9.2–17.0)	412	4.9	(4.4–5.4)	0	0.0	—
2	811	4.1	(3.9–4.4)	32	11.2	(8.0–15.5)	250	3.0	(2.6–3.3)	0	0.0	—
≥3	1186	6.0	(5.7–6.4)	55	19.3	(15.1–24.3)	342	4.0	(3.6–4.5)	2	66.7	(9.6–97.4)

Retrieved from Dunning J, Daly JP, Lomas JP, Lecky F, Batchelor J, Mackway-Jones K; Children's Head Injury Algorithm for the Prediction of Important Clinical Events Study Group. Derivation of the Children's Head Injury Algorithm for the Prediction of Important Clinical Events decision rule for head injury in children. *Arch Dis Child.* 2006;91(11):885–891 and Kuppermann N, Holmes JF, Dayan PS, et al; Pediatric Emergency Care Applied Research Network. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study [published correction appears in *Lancet.* 2014;383(9914):308]. *Lancet.* 2009;374(9696):1160–1170. —, not applicable.

[a] TBI-CT includes those with and without ciTBI by definition.

Study Procedures

Patients were enrolled by the treating ED clinician, who then collected predictive clinical data before any neuroimaging. The research assistant recorded ED and hospital management data after the visit and conducted a telephone follow-up with patients who had not undergone neuroimaging.

Statistical Analysis

Data were entered into EpiData (The EpiData Association, Odense, Denmark) and later Research Electronic Data Capture[20] and analyzed by using Stata 13 (StataCorp, College Station, TX). Descriptive statistics were calculated for key variables with 95% confidence intervals (CIs) when relevant.

We compared the rates of ciTBI and TBI-CT with and without isolated vomiting. Isolated vomiting was defined as vomiting without an association with predictor variables of head injury as defined in both the PECARN rules (<2 and ≥2 years old) and the CHALICE rule.[9,10] Of note, the PECARN CDR for those <2 years old did not include vomiting as a predictor variable. In addition, we undertook a multivariate logistic regression analysis to assess the independent associations of head injury signs and symptoms with the presence of ciTBI and TBI-CT.

RESULTS

Of the 19 920 eligible children enrolled in the APHIRST cohort study, 3389 (17.0%; 95% CI 16.5%–17.5%) had a history of any vomiting, with 1006 (29.7%) with isolated vomiting without any other CDR predictors. There were 1398 (41.3%) girls, and the mechanism of head injury was most commonly a fall (*n* = 2628; 78.8%; Table 2). Seventy-six of the 172 children with a ciTBI (44.2%; 95% CI 36.9%–51.7%) and 123 of the 285 children with TBI-CT (43.2%; 95% CI 37.5%–49.0%) had any history of vomiting (Table 3).

When applying our cohort data solely to the CHALICE rule predictors for those with isolated vomiting <3 times (*n* = 662 of 1006; 65.8%) and ≥3 times (*n* = 344 of 1006; 34.2%), there were 0 and 1 child with ciTBI, respectively, and 0 and 2 children with a TBI-CT, respectively (Table 4).

Significant associations for ciTBI when 1 additional symptom and/or sign was added to vomiting <3 times included the following: suspicion of depressed or penetrating skull fracture (*n* = 9 of 34; 26.5%; 95% CI 11.4%–41.5%; *P* < .001), signs of base of skull fracture (*n* = 3 of 17; 17.7%; 95% CI 0.0%–13.9%; *P* = .005), seizure (*n* = 6 of 45; 13.3%; 95% CI 3.3%–23.4%; *P* < .001), altered GCS (*n* = 5 of 43; 11.6%; 95% CI 1.9%–21.3%; *P* = .002), drowsiness (*n* = 16 of 158; 10.1%; 95% CI 5.4%–14.9%; *P* < .001), as well as the high-risk mechanisms of high-speed motor vehicle crash (MVC) (*n* = 10 of 90; 11.1%; 95% CI 4.6%–17.6%; *P* < .001) and fall from >3 m (*n* = 9 of 145; 6.2%; 95% CI 2.3%–10.2%; *P* = .003). When vomiting occurred ≥3 times, the significant associations were abnormal drowsiness (*n* = 14 of 158; 8.9%; 95% CI 4.4%–13.3%; *P* < .001), seizure (*n* = 2 of 15; 13.5%; 95% CI 0.0%–31.1%; *P* = .049), altered GCS (*n* = 3 of 35; 8.6%; 95% CI 0.0%–18.0%; *P* = .050), and the high-risk mechanisms of high-speed MVC (*n* = 3 of 35; 8.6%; 95% CI 0.0%–18.0%; *P* = .050) and fall from >3 m (*n* = 9 of 102; 8.8%; 95% CI 3.3%–14.4%; *P* < .001).

TABLE 4 Prevalence of Traumatic Brain Injuries in APHIRST Patients With Isolated Vomiting and Vomiting Plus 1 Other Factor Based on Age-Specific CHALICE Prediction Rule Factors

	ciTBI				P^a	TBI-CT[b]				P^a
	n	*N*	%	95% CI		*n*	*N*	%	95% CI	
Isolated vomiting <3 times only	0	662[c]	0.0	(0.0–0.0)	<.001	0	662[c]	0.0	(0.0–0.0)	<.001
Plus LOC >5 min	1	12	8.3	(0.0–24.7)	.229	3	12	25.0	(0.0–50.6)	.005
Plus amnesia >5 min	5	117	4.3	(0.6–8.0)	.102	8	117	6.8	(2.2–11.4)	.029
Plus abnormal drowsiness	16	158	10.1	(5.4–14.9)	<.001	21	158	13.3	(8.0–18.6)	<.001
Plus suspicion of NAI	1	15	6.7	(0.0–19.7)	.278	3	15	20.0	(0.0–41.0)	.011
Plus seizure	6	45	13.3	(3.3–23.4)	<.001	8	45	17.8	(6.5–29.1)	<.001
Plus GCS <14, or 15 if age <1 y	5	43	11.6	(1.9–21.3)	.002	7	43	16.3	(5.1–27.4)	<.001
Plus suspicion of depressed or penetrating injury	9	34	26.5	(11.4–41.5)	<.001	13	34	38.2	(21.7–54.8)	<.001
Plus signs of base-of-skull fracture	3	17	17.7	(0.0–36.3)	.005	5	17	29.4	(7.1–51.7)	<.001
Plus positive neurology	2	34	5.9	(0.0–13.9)	.164	4	34	11.8	(0.8–22.8)	.021
Plus presence of bruise, swelling, or laceration >5 cm if age <1 y	8	341	2.4	(0.7–4.0)	.688	14	341	4.1	(2.0–6.2)	.310
Plus high speed MVC	10	90	11.1	(4.6–17.6)	<.001	12	90	13.3	(6.3–20.4)	<.001
Plus fall from >3 m	9	145	6.2	(2.3–10.2)	.003	15	145	10.3	(5.4–15.3)	<.001
Plus high-speed injury from a projectile or other object	4	101	4.0	(0.1–7.8)	.168	5	101	5.0	(0.7–9.2)	.249
Isolated vomiting ≥3 times only	1	344[c]	0.3	(0.0–0.9)	.001	2	344[c]	0.6	(0.0–1.4)	<.001
Plus LOC >5 min	1	3	33.3	(0.0–98.7)	.071	2	3	66.7	(1.3–100.0)	.006
Plus amnesia >5 min	2	72	2.8	(0.0–6.6)	.691	6	72	8.3	(1.9–14.8)	.128
Plus abnormal drowsiness	14	158	8.9	(4.4–13.3)	<.001	22	158	13.9	(8.5–19.3)	<.001
Plus suspicion of NAI	1	8	12.5	(0.0–37.0)	.178	1	8	12.5	(0.0–37.0)	.305
Plus seizure	2	15	13.3	(0.0–31.1)	.049	2	15	13.3	(0.0–31.1)	.140
Plus GCS <14, or 15 if age <1 y	3	35	8.6	(0.0–18.0)	.050	4	35	11.4	(0.7–22.1)	.065
Plus suspicion of depressed or penetrating injury	1	15	6.7	(0.0–19.7)	.309	3	15	20.0	(0.0–41.0)	.026
Plus signs of base-of-skull fracture	2	23	8.7	(0.0–20.5)	.104	5	23	21.7	(4.5–39.0)	.003
Plus positive neurology	0	27	0.0	(0.0–0.0)	>0.999	0	27	0.0	(0.0–0.0)	.629
Plus presence of bruise, swelling, or laceration >5 cm if age <1 y	3	126	2.4	(0.0–5.1)	>0.999	5	126	4.0	(0.6–7.4)	>0.999
Plus high-speed MVC	3	35	8.6	(0.0–18.0)	.050	3	35	8.6	(0.0–18.0)	.200
Plus fall from >3 m	9	102	8.8	(3.3–14.4)	<.001	13	102	12.8	(6.2–19.3)	<.001
Plus high-speed injury from a projectile or other object	2	59	3.4	(0.0–8.1)	.650	3	59	5.1	(0.0–10.7)	.743

Retrieved from Dunning J, Daly JP, Lomas JP, Lecky F, Batchelor J, Mackway-Jones K; Children's Head Injury Algorithm for the Prediction of Important Clinical Events Study Group. Derivation of the Children's Head Injury Algorithm for the Prediction of Important Clinical Events decision rule for head injury in children. *Arch Dis Child.* 2006;91(11):885–891.

[a] Fisher's exact *P* value.

[b] TBI-CT includes those with and without ciTBI.

[c] Total isolated and nonisolated vomiting.

The 2 PECARN rules (<2 and ≥2 years old) applied different CDR predictor variables compared with the CHALICE (Table 5). Of the subsample of 457 of 1006 (45.4%) children <2 years old with isolated vomiting, none had ciTBI or TBI-CT in our cohort. In the 549 (54.6%) children ≥2 years old with isolated vomiting, 1 (0.3%; 95% CI 0.0%–0.9%) had ciTBI and 2 (0.6%; 95% CI 0.0%–1.4%) had TBI-CT (including the 1 child with ciTBI; Table 5). Case synopses of these 2 children are presented in Table 6.

In multivariate regression, the presence of the following, in addition to vomiting, was significantly associated with ciTBI: signs of skull fracture, altered mental status, headache, and acting abnormally and with TBI-CT, signs of a skull fracture, NAI concern, and headache, and acting abnormally with the test characteristics (including sensitivity, specificity, PPVs, negative predictive values [NPVs], and adjusted odds ratios [aORs]), which are presented in Table 7.

DISCUSSION

In this large prospective observational study of children, we have confirmed that vomiting is a common symptom (17%) after a head injury at any age, but the incidence of ciTBI or TBI-CT without other symptoms and/or signs of head injury is infrequent. We have confirmed the finding of Dayan et al[15] that isolated vomiting in children is rarely associated with ciTBI or TBI-CT. The most important associations with vomiting that signal a greater risk of ciTBI include signs that are suggestive of a skull fracture, altered consciousness or behavior, and headache, and for TBI-CT, that also includes concern for NAI.

TABLE 5 Prevalence of Traumatic Brain Injuries in APHIRST Patients With Isolated Vomiting and Vomiting Plus 1 Other Factor Based on Age-Specific PECARN Predictor Variables

	ciTBI				TBI-CT[a]			
	n	*N*	%	95% CI	*n*	*N*	%	95% CI
Children age <2 y								
Isolated vomiting (ie, no other predictors)	0	457[b]	0.0	(0.0–0.0)	0	457[b]	0.0	(0.0–0.0)
Vomiting plus altered mental status (GCS <15, sleepiness, agitation)	10	124	8.1	(3.3–12.9)	17	124	13.7	(7.6–19.8)
Vomiting plus nonfrontal scalp hematoma	6	175	3.4	(0.7–6.1)	17	175	9.7	(5.3–14.1)
Vomiting plus LOC >5 s	0	37	0.0	(0.0–0.0)	1	37	2.7	(0.0–8.0)
Vomiting plus palpable skull fracture	4	34	11.8	(0.8–22.8)	13	34	38.2	(21.7–54.8)
Vomiting plus not acting normally per parent	8	196	4.1	(1.3–6.9)	14	196	7.1	(3.5–13.8)
Vomiting plus history of severe mechanism of injury	2	8	25.0	(0.0–57.1)	2	8	25.0	(0.0–57.1)
Children age ≥2 y								
Isolated vomiting (ie, no other predictors)	1	549[b]	0.2	(0.0–0.5)	2	549[b]	0.4	(0.0–0.9)
Vomiting plus altered mental status (GCS <15, sleepiness, agitation)	39	460	8.5	(5.9–11.3)	55	460	12.0	(9.0–14.9)
Vomiting plus any LOC	17	307	5.5	(3.0–8.1)	26	307	8.5	(5.4–11.6)
Vomiting plus clinical signs of basilar skull fracture	4	30	13.3	(1.0–25.7)	8	30	26.7	(10.6–42.8)
Vomiting plus severe headache	42	1104	3.8	(2.7–4.9)	64	1104	5.8	(4.4–7.2)
Vomiting plus severe mechanism of injury	17	75	22.7	(13.1–32.2)	21	75	28.0	(17.8–38.2)

Retrieved from Dayan PS, Holmes JF, Atabaki S, et al; Traumatic Brain Injury Study Group of the Pediatric Emergency Care Applied Research Network. Association of traumatic brain injuries with vomiting in children with blunt head trauma. *Ann Emerg Med.* 2014;63(6):657–665.

[a] TBI-CT includes those with and without ciTBI.

[b] Total isolated and nonisolated vomiting.

TABLE 6 Case Synopses for Patients With Vomiting With No CDR Predictors

Age, y	Sex	No. Vomits	Mechanism	Admission	Final Diagnosis
13	Male	11	Struck by small, hard ball	Observed 5 h on day of injury	CT: temporal fracture, subacute epidural hematoma, and contusion
				Represented 1 wk later with ongoing vomiting and headache then admitted for >2 d (no neurosurgery)	MRI: underlying small dural nodule on MRI with bleeding into it
3	Female	1	Fall from bicycle, no helmet	Admitted <2 nights	Occipital contusion

Consistent with the findings of Dayan et al[15] in the PECARN study, TBI-CT abnormalities in this study are more common than ciTBI. The importance of differentiating between CT abnormalities (TBI-CT) and ciTBI is that CDRs need to be sensitive for detecting head injuries that require interventions (defined in our study as either neurosurgery, intubation, or admission ≥2 nights because of the persistent signs or symptoms from the head injury) rather than injuries requiring no interventions. No child with isolated vomiting required neurosurgical intervention, and 1 child with ciTBI required a 6-day admission for bleeding into a congenital dural nodule after re-presentation to hospital 1 week after the initial presentation with head injury. This child had a large number of vomits in the ED on the first presentation and had ongoing vomiting for a week before the imaging and detection of the underlying condition.

Vomiting has been included as a prognostic symptom in a number of guidelines and CDRs for advising CT use in pediatric head injury.[7,21–23] Although some have suggested vomiting (and in particular, repeated vomiting)[21,23] is a predictor of ciTBI, a meta-analysis in 2003 revealed that vomiting did not significantly increase the relative risk of an intracranial hematoma in pooled results from 14 092 children and 7 studies, although these studies had good homogeneity.[22] The precise definition of frequency of vomiting has not been consistent in the literature and is confused by differences in the presence of vomiting in adults and children. Children may be prone to vomiting because of personal or familial predisposition rather than the presence of intracranial injury[21]; however, other studies have revealed a reduced vomiting rate in children with significant injury in comparison with children with normal CT results.[1] Researchers in many studies that include vomiting as a predictor have not defined the difference between isolated vomiting and vomiting associated with other predictor variables. This study has revealed the variables that increase the risk of both ciTBI and TBI-CT. We have sought to describe predictor variables associated with the highest risk of significant injury.

With this study, we add to evidence to assist in the rational use of cranial

TABLE 7 Diagnostic Testing of ciTBI and TBI-CT From CDR Predictors Within Vomiting Cases ($N = 3389$)

	Predicting Likelihood of ciTBI						LR+		Predicting Likelihood of TBI-CT				
	Sensitivity	Specificity	PPV	NPV	aOR	95% CI	*P*	Sensitivity	Specificity	PPV	NPV	aOR	95% CI	*P*
LOC	23.84	92.08	2.55	99.28	1.39	(0.61–3.16)	.435	20.70 2.6	92.13	3.68	98.77	1.51	(0.73–3.14)	.263
Headache	45.35	79.64	1.90	99.41	2.29	(1.28–4.11)	.005	41.40 2.0	79.72	2.88	98.94	2.55	(1.52–4.27)	<.001
Acting abnormally (according to parents)	40.12	87.10	2.64	99.40	1.86	(1.03–3.37)	.040	37.19 2.9	87.22	4.05	98.97	1.83	(1.09–3.96)	.020
Amnesia	22.67	91.82	2.36	99.27	1.24	(0.57–2.69)	.582	20.35 2.5	91.87	3.50	98.76	1.50	(0.76–2.97)	.239
Seizure	7.56	98.55	4.35	99.19	2.12	(0.65–6.85)	.211	7.02 5	98.58	6.69	98.65	1.61	(0.50–5.21)	.423
NAI concern	6.98	99.55	11.88	99.19	4.71	(0.80–27.76)	.087	5.61 13	99.57	15.84	98.64	6.75	(1.54–29.69)	.011
Altered mental status	27.33	98.00	10.63	99.36	2.35	(1.04–5.33)	.041	20.70 13.8	98.05	13.35	98.84	2.02	(0.95–4.31)	.069
Skull fracture	76.16	98.66	33.08	99.79	80.13	(43.38–148.61)	< .001	73.33 73	99.05	52.78	99.61	112.96	(66.76–191.14)	<.001
Abnormal GCS (≤13)	6.98	99.38	8.89	99.19	0.79	(0.19–3.33)	.750	5.26 8.1	99.39	11.11	98.64	0.93	(0.25–3.53)	.918
Neurologic deficit	4.07	98.69	2.63	99.16	0.46	(0.09–2.38)	.356	3.51 2.7	98.70	3.76	98.60	0.52	(0.13–2.42)	.344
Scalp hematoma	69.19	65.89	1.74	99.59	0.80	(0.44–1.46)	.465	71.23 2.1	66.12	2.96	99.37	1.24	(0.74–2.55)	.413

CT in children. It is important to recognize that CT is the gold standard investigation for the identification of intracranial injury, with results guiding subsequent management. Negative results are reassuring and facilitate patient discharge, reducing not only health care costs but parental anxiety. However, CT scans are associated with radiation risks, particularly in children with rapidly developing brains, who are more vulnerable to radiation-associated cell damage. Radiation from CT can cause lethal malignancies, with a reported lifetime mortality rate of 1 death for every 1000 to 5000 pediatric cranial CTs performed (with the highest risk in the younger age groups).[24–26]

A strength of this study was the large number of children with head injury and isolated vomiting. In this cohort, only 1 child had a ciTBI, with 1 additional child having a TBI-CT not meeting ciTBI criteria. An additional strength has been the inclusion of the PECARN CDR predictor variables for children <2 years old and the inclusion of the CHALICE definition of isolated vomiting, demonstrating that the exact number of vomiting episodes does not change the risk of ciTBI or TBI-CT. Similar to the PECARN study, we have shown that isolated vomiting alone in the <2-years-old age group was not associated with ciTBI or TBI-CT.[15] These factors are important in providing a rationale for avoiding a CT scan in younger children, reducing the risk of exposure to radiation and sedation to undertake the scan. However, the low incidence of both ciTBI in our cohort and the known long-term risk of radiation-induced malignancy means that the choice between scanning and not scanning is finely balanced. This study will assist clinicians in determining when to undertake CT scans in children with vomiting with and without other CDR predictors.

This study has a number of limitations. CT scans were obtained on a minority of patients; it would have been unethical to obtain CT scans on patients whom the clinicians did not think required them. We collected the number of vomiting episodes but did not determine the timing of vomiting episodes in relation to the head injury, which has been included as an increased risk of ciTBI.[8] However, the benefit of this observational study with extensive follow-up was that it allowed unexpected consequences of the head injury to be detected after discharge from the hospital without CT scanning. Because of the pronounced heterogeneity of the CDR predictor variables, the only way to realistically compare the variables was to create a homogenous cohort and explore the associations against the age groups and vomiting frequencies. Finally, the patients reflect a cohort from Australia and New Zealand with a bias toward tertiary-care children's hospitals, where the neuroimaging rate is lower than reported in US studies.[10,27]

CONCLUSIONS

TBI-CT is uncommon, and ciTBI is uncommon in children with minor blunt head injury when vomiting is their only sign or symptom. In children with isolated vomiting, strategies such as observation should be considered before conducting an immediate CT scan.

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ABBREVIATIONS

aOR: adjusted odds ratio
APHIRST: Australasian Paediatric Head Injury Rule Study
CATCH: Canadian Assessment of Tomography for Childhood Head Injury
CDR: clinical decision rule
CHALICE: Children's Head Injury Algorithm for the Prediction of Important Clinical Events
CI: confidence interval
ciTBI: clinically important traumatic brain injury
CT: computed tomography
ED: emergency department
GCS: Glasgow Coma Score
LOC: loss of consciousness
MVC: motor vehicle crash
NAI: nonaccidental injury
NPV: negative predictive value
PECARN: Pediatric Emergency Care Applied Research Network
PPV: positive predictive value
TBI-CT: traumatic brain injury on computed tomography

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Address correspondence to Meredith L. Borland, MBBS, Princess Margaret Hospital for Children, GPO D184, Perth, WA 6840, Australia. E-mail: meredith.borland@health.wa.gov.au

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