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Performance of a Decision Rule to Predict Need for Computed Tomography Among Children With Blunt Head Trauma

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ABSTRACT

OBJECTIVE. To assess the ability of the NEXUS II head trauma decision instrument to identify patients with clinically important intracranial injury (ICI) from among children with blunt head trauma.

METHODS. An analysis was conducted of the pediatric cohort involved in the derivation set of National Emergency X-Radiography Utilization Study II (NEXUS II), a prospective, observational, multicenter study of all patients who had blunt head trauma and underwent cranial computed tomography (CT) imaging at 1 of 21 emergency departments. We determined the test performance characteristics of the 8-variable NEXUS II decision instrument, derived from the entire NEXUS II cohort, in the pediatric cohort (0–18 years of age), as well as in the very young children (<3 years). Clinically important ICI was defined as ICI that required neurosurgical intervention (craniotomy, intracranial pressure monitoring, or mechanical ventilation) or was likely to be associated with significant long-term neurologic impairment.

RESULTS. NEXUS II enrolled 1666 children, 138 (8.3%) of whom had clinically important ICI. The decision instrument correctly identified 136 of the 138 cases and classified 230 as low risk. A total of 309 children were younger than 3 years, among whom 25 had ICI. The decision instrument identified all 25 cases of clinically important ICI in this subgroup.

CONCLUSIONS. The decision instrument derived in the large NEXUS II cohort performed with similarly high sensitivity among the subgroup of children who were included in this study. Clinically important ICI were rare in children who did not exhibit at least 1 of the NEXUS II risk criteria.

HEAD INJURY IS a common cause of emergency-department (ED) presentation, accounting for ~1 million visits annually.[1] Although the majority of patients with head trauma have a minor injury that requires no specific therapy, a small number prove to have clinically significant intracranial injury (ICI). Because of the risk of unrecognized ICI, clinicians liberally order cranial computed tomography (CT) in blunt trauma, generating annual charges of nearly $750 million while revealing significant ICI in <60 000 patients.[2–4] The overuse of CT may be even more pronounced in children, who comprise almost 40% of these patients,[5] because of the greater difficulty in assessing neurologic function in at least some of them.

A number of investigators have attempted to identify clinical criteria that accurately predict which patients are at risk for ICI and thus limit CT imaging to such patients.[3–25] Although these reports provide some preliminary evidence, limitations in study design, including retrospective chart review, small sample size, and restricted age or selection criteria, limit the strength of any of these instruments.[7–11,13–15,18–25] The National Emergency X-Radiography Utilization Study II (NEXUS II) is an ongoing, prospective, multicenter study of blunt head trauma victims that was designed to derive and subsequently validate a decision aid to identify a group of patients, from among those with head trauma, who are at very low risk for significant ICI, thus enabling a reduction in unwarranted cranial CT imaging.[26,27] The derivation set of NEXUS II identified a decision aid, based on both adult and pediatric patients, that was highly sensitive (98.3%; 95% confidence interval [CI]: 97.2–99.0) for ICI in this cohort, excluded a significant lesion with high negative predictive value (NPV: 99.1%; 95% CI: 98.5–99.5), and, if prospectively validated, should be able to identify safely a small subset of patients who can be discharged without imaging (13.7%; 95% CI: 13.1–14.3).[27]

The next phase of NEXUS II will involve validation of the decision aid. Before beginning enrollment of additional study patients, our objective with this planned subset analysis was to determine if the decision instrument was as sensitive in the pediatric subgroup as it was in the overall derivation set. Because we recognize that the pediatric population is not homogeneous and that neurologic assessment is often more difficult in the very young, we further decided to examine the performance of the instrument in the special subset of very young children who are younger than 3 years.

METHODS

NEXUS II is a multicenter, prospective, observational study of all blunt head trauma victims who had a cranial CT as part of their ED evaluation. The 21 participating centers enrolled patients throughout the study period from May 1999 to December 2000. Details of the methods are presented elsewhere[26,27] and reviewed here in brief.

Participating hospitals enrolled all blunt head trauma patients who underwent cranial CT imaging. The decision to obtain head CT was made by the ED clinicians on the basis of their own criteria and was not directed in any way by the study. These clinicians collected data on a standardized data form before ordering the CT scan. Information was available to help clinicians define study variables, but they were not required to access such information (Appendix 1). The clinicians recorded whether each of the 19 candidate criteria was present, absent, or unable to be determined (eg, it would be impossible for a comatose patient to report a severe headache; Table 1).

The diagnosis of ICI was based solely on the final CT interpretation of the clinical radiologist at the study site. We first defined significant ICI on the basis of a consensus of experts in neurosurgery, neuroradiology, and emergency medicine and then modified this on the basis of evidence from the large cohort of patients in the derivation set with 1 of these injuries (Table 2).[28,29] This refined definition of clinically important ICI reliably identifies patients who require neurosurgical intervention (craniotomy, intracranial pressure monitoring, or mechanical ventilation) or who are likely to have significant long-term neurologic impairment.[29] The decision instrument that was subsequently derived was required to demonstrate extremely high sensitivity while at-

TABLE 1   **Candidate Variables**

1. Spontaneous eye opening
2. Orientation
3. Ability to follow commands
4. Seizure after trauma
5. Loss of consciousness
6. Prolonged loss of consciousness
7. Severe or progressive headache
8. Coagulopathy
9. Abnormal behavior
10. Abnormal level of alertness
11. Evidence of significant skull fracture
12. Persistent vomiting
13. Evidence of intoxication
14. Motor deficit
15. Gait abnormality
16. Abnormal cerebellar function
17. Cranial nerve abnormality
18. Inability to read or write
19. Scalp hematoma
20. Neurologic deficit[a]

Physicians reported whether each of the first 19 variables was present, absent, or unable to be determined (unknown). The 20th variable was a composite score created for data analysis. Definitions and scoring instructions are listed in Appendix 1.

[a] Neurologic deficit is a composite variable combining the responses to the first 3 items of the Glasgow Coma Scale score (spontaneous eye opening, orientation, ability to follow commands), motor deficit, gait abnormality, abnormal cerebellar function, and cranial nerve abnormality. Patients were assigned an abnormal value (neurologic deficit positive) if any of the constituent variables were abnormal and were only assigned a normal value if all constituent variables were classified as normal.

TABLE 2 CT Findings Representing Clinically Important ICI

1. Substantial epidural or subdural hematoma (>1.0 cm in width or causing mass effect)
2. Substantial cerebral contusion (>1.0 cm in diameter or >1 site)
3. Extensive subarachnoid hemorrhage
4. Mass effect or sulcal effacement
5. Signs of herniation
6. Basal cistern compression or midline shift
7. Hemorrhage in the posterior fossa
8. Intraventricular hemorrhage
9. Bilateral hemorrhage of any type
10. Depressed or diastatic skull fracture
11. Pneumocephalus
12. Diffuse cerebral edema
13. Diffuse axonal injury

tempting to retain the maximal possible specificity with regard to identifying these cases of clinically important ICI.[26]

We analyzed the 19 candidate variables in the entire set of study patients (including adults) with classification and regression trees[30] and binary recursive partitioning to construct the decision aid. Details of the analysis have been described previously.[26,27] These candidate variables were chosen by consensus of the study investigators because they had been described as possibly being predictive of ICI in previous literature,* and each of them was shown during the derivation study to exhibit a high level of raw agreement, as well as a $\kappa > 0.50$.[31]

The optimum decision instrument derived for the entire study cohort of 13 728 patients is composed of the following 8 variables: evidence of significant skull fracture, altered level of alertness, neurologic deficit, persistent vomiting, presence of scalp hematoma, abnormal behavior, coagulopathy, and age >65 years.[26] This instrument had a sensitivity of 98.3% (95% CI: 97.2–99.0) and a specificity of 13.7% (95% CI: 13.1–14.3) in all study patients.

This current subset analysis evaluates the test characteristics of the derived decision instrument with regard to all pediatric patients (0–18 years of age) who were enrolled in the study. Because none of the children met the last criterion of "age >65 years," we modified the decision instrument slightly to include only the other 7 criteria. For the rule to be clinically useful in children, it must retain very high sensitivity (at least 98.5%) and NPV (so as not to miss cases of clinically significant ICI), as well as some reasonable degree of specificity (so as to allow some reduction in CT imaging). We acknowledge that our definition of clinically important ICI means that some patients with abnormalities on CT will not be identified; however, our specific aim is to identify patients who most likely will need an intervention. It is clear that even patients without CT abnormalities are at risk for neurologic sequelae; therefore, we believe the

optimal rule that will be acceptable to physicians would be one in which at least 98.5% of patients with clinically important ICI are identified.

We performed a secondary analysis of the decision instrument, in the special population of very young children (<3 years of age), because we believed that assessing behavior and neurologic function, as well as other candidate criteria, might be more difficult in this age group,[9,11,12,15,22] and we wanted to determine whether the instrument retained desirable test characteristics in this very young cohort.

The study protocols and methods were reviewed by the federal Office for the Protection from Research Risks, as well as by the institutional review board at each site, and appropriate waivers were granted to each participating institution. Data analysis was performed with Stata 6.0 (Stata Corp, College Station, TX).

RESULTS

The 21 participating centers enrolled 1666 pediatric patients with closed head trauma. The age distribution of enrolled patients was J-shaped, with approximately half of the patients (844) either ≤3 years of age or ≥15 years of age (Fig 1). Demographics of the sample are presented in Table 3. A total of 205 children with blunt trauma had evidence of traumatic injury on head CT, 67 cases were injuries that do not require therapeutic intervention, and 138 (8.3%) children had findings that met our criteria for clinically important ICI. ICI was slightly more common in patients who were ≥15 years of age but was otherwise evenly distributed among all age groups (Fig 1).

The 138 children with significant ICI sustained a total of 332 distinct injuries (median: 3 injuries per patient; range: 1–7; Table 4). The 67 children with "minor" in-
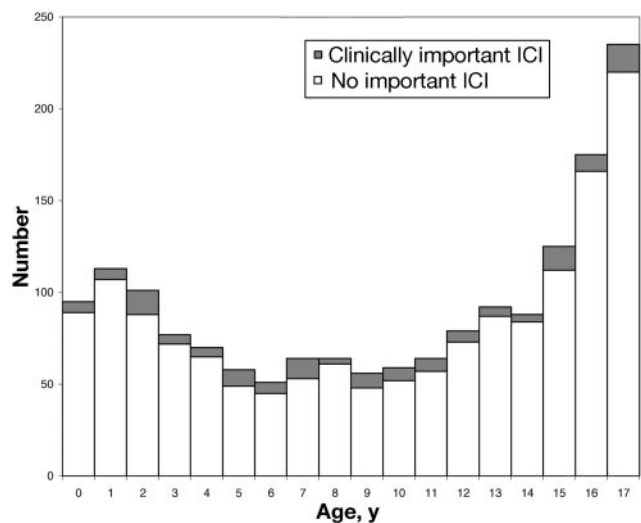

FIGURE 1
Age distribution of the 1666 pediatric blunt trauma victims. A total of 138 children had clinically important ICI that was identified on CT imaging.

* Refs 2–4, 6, 10, 12–14, 19, 20, and 23–25.

TABLE 3 Demographics of the Study Sample

	No Clinically Important ICI (n = 1528)	Clinically Important ICI (n = 138)	Entire Sample (n = 1666)
Age, median (IQR), y	11.6 (4.4–16.0)	9.9 (4.8–15.1)	11.3 (4.4–15.9)
Male, n (%)	985 (64)	87 (63)	1072 (64)
Ethnic background, n (%)			
White	745 (48.8)	69 (50.0)	814 (48.9)
Black	247 (16.2)	13 (9.4)	260 (15.6)
Hispanic	305 (20.0)	32 (23.2)	337 (20.2)
Asian	37 (2.4)	5 (3.6)	42 (2.5)
Middle Eastern	10 (0.6)	1 (0.7)	11 (0.7)
Native American	19 (1.2)	0	19 (1.1)
Unknown	165 (10.8)	18 (13.0)	183 (11.0)

IQR indicates interquartile range.

TABLE 4 Types of Injuries Noted in the 138 Patients With Clinically Important ICI Identified on CT

Type of Injury	Patients With Clinically Important ICI (N = 138)
Skull fractures	
Linear	34
Basilar	2
Depressed	21
Diastatic	6
Complex	8
Extra-axial bleed	
Epidural	24
Acute subdural	37
Subacute subdural	0
Chronic subdural	1
Acute or chronic subdural	0
Extra-axial, not specified	17
Subarachnoid hemorrhage	33
Intraventricular hemorrhage	11
Parenchymal lesions	
Intraparenchymal hemorrhage	19
Contusion/petechial hemorrhage	73
Focal edema	1
Diffuse edema	12
Shift or mass effect	22
Herniation	6
Diffuse axonal injury	2
Brain laceration	0
Pneumocephalus	27
Other (eg, shear injury, infarct, pineal hemorrhage)	13

Patients often had >1 injury noted on CT.

juries noted on CT had a total of 101 abnormalities on CT scan (median: 2; range: 1–4).

The most frequently noted abnormal criteria in those with ICI were abnormal neurologic examination (including Glasgow Coma Scale score <15), altered level of alertness, disoriented, no spontaneous eye opening, prolonged loss of consciousness, and abnormal behavior (Table 5). Physicians were able to define the presence or absence of most candidate variables in most patients (Appendix 2). Prolonged loss of consciousness, gait abnormality, abnormal cerebellar function, and inability to read or write were the variables that most commonly were reported as unknown or unable to assess. The lower CIs for the interrater assessments (κ values) for 2 variables, seizure and abnormal cerebellar function, did not exceed our prespecified level of 0.50 and thus may be of limited utility in developing a reliable instrument.

When applied to the pediatric cohort, the NEXUS II decision instrument (not including the criterion of advanced age) performed similarly to the way it did in the overall NEXUS II population to identify clinically important ICI. The decision instrument correctly identified 136 of the 138 cases (sensitivity: 98.6%; 95% CI: 94.9–99.8) and classified 230 as low risk (NPV: 230 of 232 [99.1%]; 95% CI: 96.9–99.9; specificity: 230 of 1528 [15.1%]; 95% CI: 13.3–16.9).

Two pediatric cases with ICI were not identified using this decision instrument. One of these cases likely represents an error in assessment (an 8-year-old with slight diastasis of the coronal suture was noted to have a large scalp hematoma on tomographic imaging), whereas the other child (a 7-year-old with a small hemorrhagic contusion in the right occipital-temporal area) did not have any of the rule criteria. Neither of these children required neurosurgical intervention.

Among the 309 children who were younger than 3 years, 55% of whom were male, there were 25 (8.1%) cases of clinically important ICI. At least 1 of the 7 candidate variables of the decision instrument was recorded as present in each of the children with significant ICI. The single most common finding in those with clinically important ICI was altered level of alertness, whereas scalp hematoma was also fairly common (Table 5). Of note, clinicians were unable to assess neurologic function completely in 8 of the 25 injured children, but each of these individuals exhibited at least 1 of the other risk factors (Appendix 2). In this sample the decision instrument identified all 25 cases of clinically important ICI (sensitivity: 100%; 95% CI: 86.3–100) and classified 15 cases as low risk (specificity: 5.3%; 95% CI: 3.0–8.6; NPV: 100%; 95% CI: 78.2–100).

DISCUSSION

NEXUS II is the largest prospective study to date to derive a decision instrument regarding the need for head

TABLE 5 Frequency of Individual Candidate Criteria

Criterion	0–18 y		0–3 y	
	No ICI (N = 1528), %	ICI (N = 138), %	No ICI (N = 284), %	ICI (N = 25), %
Spontaneous eye opening	94	48	93	48
Oriented	88	36	77	33
Able to follow commands	91	44	73	33
Seizure after the trauma	6	6	9	8
Loss of consciousness	55	75	32	64
Prolonged loss of consciousness (reliably witnessed, >5 min)	7	42	8	38
Severe or progressive headache	15	20	5	0
Coagulopathy[a]	1	7	3	4
Abnormal behavior[a]	23	48	36	55
Altered level of alertness[a]	27	66	31	68
Evidence of significant skull fracture[a]	3	28	2	11
Persistent vomiting[a]	11	24	13	13
Evidence of intoxication	5	4	1	0
Motor deficit	3	21	2	26
Gait abnormality	5	21	6	22
Abnormal cerebellar	2	12	1	22
Cranial nerve abnormality	15	2	1	20
Inability to read or write	11	53	36	64
Scalp hematoma[a]	37	59	41	65
Composite score, neurologic deficit[a,b]	32	81	54	81
GCS 15[c]	82	31	58	26

In this table, ICI refers to cases of clinically important ICI. The numbers in the cells represent the percentage at which each criterion was present, among all of the cases in which the physician stated that the criterion was assessable (ie, not unknown or unable to assess). GCS indicates Glasgow Coma Scale.

[a] These 7 criteria compose the decision instrument.

[b] Neurologic deficit is a composite variable that combines the responses to the first 3 items of the Glasgow Coma Scale score (spontaneous eye opening, orientation, ability to follow commands), motor deficit, gait abnormality, abnormal cerebellar function, and cranial nerve abnormality.

[c] Normal GCS (GCS 15) was not assessed by the physicians but calculated for each patient on the basis of the reported individual criteria.

CT in blunt head trauma. Previous studies have addressed this same problem, both in adults[3,4,8,17,19,20,23–25] and in children[4,7–11,13–15,18–25] but have not been able to develop an instrument applicable to all age groups, with CIs for their performance characteristics far too wide to allow any of them to be clinically acceptable at this time.

The NEXUS II decision instrument[27] performed as well among children, including very young children (<3 years of age) as it did in the entire derivation data set, retaining the requisite high sensitivity (98.6%) and NPVs (99.1%) needed for a useful clinical decision instrument. In addition, the very large number of patients studied (even among the pediatric subgroup) allows us to have substantial confidence regarding the precision of our results. Our findings suggest that significant ICI is extremely unlikely in any child who does not exhibit at least 1 of the following high-risk criteria: (1) evidence of significant skull fracture (diastatic, depressed, open, or basilar); (2) altered level of alertness; (3) neurologic deficit; (4) persistent vomiting; (5) presence of scalp hematoma; (6) abnormal behavior; and (7) coagulopathy. Although the final decision guide is composed of 8 distinct criteria, the instrument actually involves only 5 assessments. Examining for evidence of skull fracture and scalp hematoma is equivalent to determining whether there is evidence of significant trauma to the calvarium, whereas examining for focal neurologic deficits, abnormal level of alertness, and abnormal behavior is equivalent to assessing whether there is any evidence of neurologic impairment. The remaining 3 criteria (persistent vomiting, coagulopathy, and age >65) require separate independent evaluations.

The number of injuries missed by the instrument was 2 in 1666 evaluations. This false-negative rate is of a magnitude slightly greater than the potential lethal malignant transformation rate (1 in 1000) associated with the liberal use of CT scanning.[32] Although it of course would be optimal to have an instrument that identifies every such injury, it is clear that this could be accomplished only by performing CT scanning of every child with head trauma. In this context, it is further reassuring that among the very few children with ICI missed by the decision instrument, it is likely that almost none will have a serious adverse outcome as a result of such injury. Neither of the children who were missed by the decision instrument in our derivation cohort had an abnormal neurologic examination or developed delayed clinical deterioration. All of the other patients in our cohort who had a similar injury on CT but in whom there were delayed clinical deterioration were easily identifiable as neurologically abnormal on their initial presentation.

Although the specificity of the NEXUS II instrument is low, it still offers some additional benefit to clinical judgment and seems to be capable of improving use of CT resources and limiting unnecessary imaging and its attendant risks (eg, need for sedation, time away from monitored environment, radiation exposure). The specificity measured in this study likely underestimates the true specificity of the instrument in evaluating all children with blunt head trauma, because of the nature of study enrollment. The study enrolled only children who underwent CT scanning; such children exhibited some characteristic, undoubtedly including those criteria incorporated in the decision instrument, that prompted a clinician to obtain imaging. Children whose finding did not raise the suspicion of ICI were less likely to be imaged. Consequently, the individual criteria are likely to be less prevalent among children who were not imaged, and the true specificity of the instrument among all children with blunt head injury is likely to be higher. It is also important to note that we deliberately focused on developing an instrument with high sensitivity and high NPV. Consequently, patients who are classified as "low risk" by the instrument are very unlikely to have significant injuries. This allows the instrument to reduce overall imaging rates safely. However, the instrument has relatively modest specificity and positive predictive value, and the majority of "non–low-risk" patients do not actually have ICIs. This raises the possibility that clinical judgment could play a role in deciding whether to image some "non–low-risk" patients. However, we have not specifically evaluated the safety of this approach and cannot endorse such practice at the current time.

Greenes and Schutzman[11] found that 19% of children who were younger than 2 years and had ICI after blunt head injury were asymptomatic. Assessing neurologic function and the potential for ICI can be particularly challenging in very young children who have limited verbal and cognitive skills. Our decision instrument seems to be sensitive for ICI in very young patients, as it correctly identified all patients who were younger than 3 years and had a clinically significant ICI. Clinicians were able to evaluate level of alertness and neurologic function in many of these children and when unable to do so found other criteria suggestive of significant ICI and need for imaging. Nevertheless, these findings require validation in a substantially larger cohort of patients, and until this is completed, clinicians should be cautious in evaluating very young children.

Several limitations should be noted. To be enrolled in this study, a patient had to have had a head CT ordered, which was done at the discretion of the treating physician and not dictated by the protocol. It is possible that most patients with a seemingly benign mechanism of injury and/or a normal examination did not undergo CT and therefore were not included in the study; it of course

is possible that some such patients had an ICI that was not identified. However, long-term follow-up interviews were conducted on 1266 patients who had sustained blunt head trauma but did not undergo emergent head CT scanning at the time of their initial ED presentation. CT imaging was ultimately obtained in 27 (2.1%) of these patients, MRI was obtained in 29 (2.3%), and 14 underwent skull radiography. No significant ICI was found among the 70 imaged patients. Among the entire 1266 follow-up cohort, there were no cases of missed ICI, none of the patients underwent subsequent hospitalization or neurosurgical intervention to treat ICI, and there were no deaths as a result of ICI.[27] We did not collect data on mechanism of injury and therefore cannot comment on this aspect of the epidemiology in our sample or whether adding specific details about the mechanism of injury could improve the operator characteristics of our rule.

We chose not to provide rigid definitions for each of the candidate criteria but rather provided descriptions of possible markers for the presence of each characteristic. We avoided rigid definitions to allow clinicians to judge these elements as part of their routine clinical assessment. We believe that this strategy improves the external validity of the decision aid. All 7 criteria are basic elements of a history and physical examination and have demonstrated high interrater reliability.[31]

Although the test characteristics of the decision aid suggest that it could be useful in clinical practice, it is important to note that this is a derivation study only and must be validated in a separate cohort before it can be recommended for widespread adoption. In addition, among the subset of patients who were younger than 3 years, for whom the sample size is small, the CIs for sensitivity and NPV are wide, making additional prospective validation in a larger cohort even more crucial.

The NEXUS II decision aid was derived in a cohort of patients of all ages. Although in this study we have shown that its performance among children was equivalent to that for the entire cohort, it is possible that a separate evaluation based only on the pediatric patients (using the same recursive partitioning methods) would have identified a different "optimal instrument," with better test characteristics among children.

CONCLUSIONS

This analysis indicates that the 7-criteria decision instrument derived in NEXUS II, as amended for children, accurately identifies a group of children among those who have sustained blunt head trauma who are at very low risk for a significant ICI. Cranial CT imaging seems unlikely to detect clinically important ICI in children who do not exhibit at least 1 of the following risk criteria: (1) evidence of significant skull fracture; (2) altered level of alertness; (3) neurologic deficit; (4) persistent vomiting; (5) presence of scalp hematoma; (6) abnormal

behavior; and (7) coagulopathy. If this is validated prospectively in a separate cohort of children, then this instrument could offer financial and health benefits through reduced charges and radiation exposure associated with decreased CT imaging.

APPENDIX 1: Physician Instructions, Guidelines, and Medical Definitions

Each patient who is seen in the ED will receive medical care consistent with current practice standards (advanced trauma life support, advanced cardiac life support, pediatric advance life support, etc). Study execution should not influence clinical decisions or care. The following definitions are for the study purposes only and do not represent recommendations for patient evaluation.

Eligible Patients

Any victim with blunt head trauma is eligible for inclusion in this study. Every blunt trauma patient who undergoes head CT must be enrolled in the study. It currently is not possible to exclude reliably ICIs in blunt head trauma victims who have any of the following: (1) posttraumatic seizure, (2) loss of consciousness (particularly if longer than 5 minutes), (3) severe or progressive headache, (4) coagulopathy (whether hereditary, drug induced, or acquired), (5) abnormal behavior, (6) abnormal level of alertness, (7) signs of basilar or depressed skull fracture, (8) recurrent or forceful vomiting, (9) evidence of intoxication, (10) motor deficit, (11) gait abnormality, (12) cerebellar abnormality, (13) cranial nerve abnormality, (14) inability to read and write name, (15) scalp hematoma, or (16) 65 years or older. Such patients are at risk for ICIs and should be treated appropriately.

Exclusions

Data forms should be completed on all patients who undergo head CT. Patients who undergo CT for reasons other than blunt trauma may have additional indications for imaging studies. This would include patients' being evaluated for penetrating trauma, infections, cerebrovascular accidents, tumors, or any other atraumatic indications. Data will be collected on these patients even though they will not be entered into the blunt head injury study.

The following terms are defined for purposes of clarity and to ensure consistent data collection. They do not represent recommendations for patient evaluation, and they should be considered subject to interpretation by individual physicians.

- A posttraumatic seizure is any seizure that follows the traumatic event (witnessed by either examining physicians or other reliable observer).

- Loss of consciousness is based on the patient's report of being knocked unconscious or a witnesses report that the patient lost consciousness or did not respond to external stimuli (including verbal stimuli or physical stimuli, eg, prodding, shaking, and pinching, among others) for some interval after the event.

- Loss of consciousness longer than 5 minutes is based on a report by a reliable witness (eg, a paramedic, health care worker, examining physician) that the patient lost consciousness for >5 minutes.

- Severe or progressive headache is any head pain deemed by the patient to be severe or progressive in nature.

- Coagulopathy is any impairment of normal blood clotting such as occurs in hemophilia, secondary to medications (eg, Coumadin, heparin, aspirin), hepatic insufficiency, and other conditions.

- Abnormal behavior is any inappropriate action displayed by the victim. It includes such things as excessive agitation, inconsolability, refusal to cooperate, lack of affective response to questions or events, and violent activity.

- Abnormal level of alertness is evidenced by a variety of findings, including but not limited to a Glasgow coma score of 14 or less; delayed or inappropriate response to external stimuli; excessive somnolence; disorientation to person, place, time or events; inability to remember 3 objects at 5 minutes; perseverating speech; and other findings.

- Significant skull fracture includes but is not limited to any signs of basilar skull fracture (periorbital or periauricular ecchymoses, hemotympanum, and drainage of clear fluid from the ears or nose) or signs of depressed or diastatic skull fracture (a palpable step-off of the skull, a stellate laceration from a point source, or any injury produced by an object striking a localized region of the skull [eg, a baseball bat, club, pool cue, golf-ball, baseball, pipe]).

- High-risk vomiting is evidenced by recurrent, projectile, or forceful emesis (either observed or by history) after trauma or vomiting associated with altered sensorium.

- Evidence of intoxication includes the following: (1) a history of intoxication or recent intoxicating ingestion is provided by a patient or observer; (2) test of bodily secretions (blood, urine, saliva, breath, etc) is positive for drugs or alcohol; (3) patient has physical evidence suggesting intoxication (odor of alcohol, slurred speech, ataxia, dysmetria or other cerebellar findings) or behavior consistent with intoxication and unexplained by medical or psychiatric illness.

- A motor deficit is a finding of abnormal weakness in any 1 or more of the 4 extremities, as determined by systematic testing of muscle strength in all 4 limbs.

- Gait abnormality is the inability to walk normally as a result of inadequate strength, loss of balance, or ataxia; it is determined by systematic testing of gait, including tandem and heel-to-toe walking, and Romberg testing.

- Cerebellar abnormality is manifested by ataxia, dysmetria, dysdiadokinesis, or other impairment of cerebellar function; it is determined by systematic testing of cerebellar function, including tests of ataxia, and finger-nose-finger, heel-to-shin, and rapid alternating movement testing.

- Cranial nerve abnormality is an abnormality of cranial nerves II to XII; it is determined by systematic testing of each of these cranial nerves.

- The ability to read and write is determined by asking the patient to read the physician's name from an identifying badge or a written piece of paper and subsequent ability to write that same name.

- A significant scalp hematoma includes any swelling of traumatic origin to the soft tissues overlying the calvarium. Injuries to the face, neck, and jaw are not considered scalp hematomas.

APPENDIX 2 Frequency With Which Physicians Could Assess Each Criterion

Criterion	0–18 y		0–3 y	
	No ICI (N = 1528), %	ICI (N = 138), %	No ICI (N = 284), %	ICI (N = 25), %
Spontaneous eye opening	100	99	99	100
Oriented	87	93	48	84
Able to follow commands	93	96	65	84
Seizure after the trauma	91	78	87	76
Loss of consciousness	77	81	79	88
Prolonged loss of consciousness (reliably witnessed, >5 min)	72	69	78	64
Severe or progressive headache	82	51	44	40
Coagulopathy[a]	80	65	69	60
Abnormal behavior[a]	98	90	94	88
Altered level of alertness[a]	98	97	97	96
Evidence of significant skull fracture[a]	93	87	90	76
Persistent vomiting[a]	99	97	98	92
Evidence of intoxication	98	92	99	96
Motor deficit	95	78	93	76
Gait abnormality	55	30	52	36
Abnormal cerebellar	40	70	60	36
Cranial nerve abnormality	86	54	79	60
Inability to read or write	54	42	36	44
Scalp hematoma[a]	84	81	84	68
Composite score, neurologic deficit[a]	62	86	47	84

[a] These 7 criteria compose the decision instrument.

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