Intracranial Pathology in Elders with Blunt Head Trauma

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Abstract

Objectives: To examine presentations and prevalence of head injury among elder victims of blunt trauma and to estimate the prevalence of occult injuries associated with a normal level of consciousness, absence of neurologic deficit, and no evidence of significant skull fracture.

Methods: The study population consisted of all patients aged 65 years or older enrolled in the National Emergency X-Radiography Utilization Study (NEXUS) II head injury cohort. The authors assessed the prevalence and patterns of intracranial injuries among this cohort and compared the prevalence of specific presenting signs and symptoms among injured and uninjured patients. An occult injury subcohort was also constructed, and injury prevalence was examined among this group.

Results: A total of 1,934 elder patients were identified among the 13,326 subjects in NEXUS II (14.5%). Significant intracranial injury, defined as an injury that typically requires procedural intervention or is associated with persistent neurologic impairment or long-term disability, was found in 178 elder patients (9.2%; 95% confidence interval = 8.0% to 10.6%) as compared with 697 individuals among 11,392 younger patients (6.1%; 95% confidence interval = 5.7% to 6.6%). Focal neurologic deficits were present in 55.8% of elder patients with injury. Prevalence of specific injuries among elder and younger patients, respectively, included the following: subdural hematoma, 4.4% and 2.4%; contusion, 4.0% and 3.2%; epidural hematoma, 0.5% and 1.0%; and depressed skull fracture, 0.2% and 0.5%. Forty-two elder patients (2.2%) had an occult injury, compared with only 92 younger patients (0.8%).

Conclusions: Elder patients with head trauma are at higher risk of developing a significant intracranial injury, including subdural and epidural hematoma. An occult presentation is also more common in elders.

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Clinically significant intracranial injury, defined here as injuries that often require intervention including endotracheal intubation, intracranial pressure monitoring, and craniotomy, or are associated with persistent neurologic impairment or long-term disability, occurs most commonly in men aged 18–55 years.[1] Seemingly trivial mechanisms of injury, such as a ground-level fall, may produce significant intracranial injury in elder individuals, who also appear to be at increased risk.[2] Injury assessment may be further compromised by coexistent mental impairment, and some older patients have additional pretrauma intracranial pathology that can contribute to the presentation or morbidity of their injury. In the face of significant intracranial injury, older patients may also be more likely to have a clinically occult presentation, which we defined as a normal level of consciousness, absence of neurologic deficit, and no evidence of open, depressed, basilar, or diastatic skull fracture. Cerebral atrophy can allow an intracranial mass lesion to accumulate without early adverse

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A list of collaborating centers and investigators appears in Appendix A.

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Table 1
Clinical Variables Documented before CT Imaging

1. Posttraumatic seizure: witnessed by a reliable observer
2. Loss of consciousness: based on the patient's report of being knocked unconscious or a report by a witness that the patient lost consciousness or did not respond to verbal stimuli or physical stimuli following the event.
3. Loss of consciousness longer than five minutes: based on a reliable report
4. Abnormal level of alertness: evidenced by a GCS $\leq$14; delayed or inappropriate response to external stimuli; excessive somnolence; disorientation to person, place, time, or events; inability to remember three objects at five minutes; perseverating speech
5. Significant skull fracture: includes any signs of basilar, depressed, or diastatic skull fracture
6. High-risk vomiting: recurrent, projectile, or forceful emesis or vomiting associated with altered sensorium
7. Evidence of intoxication: including a) a history of intoxication or recent intoxicating ingestion provided by the patient or observer; b) test of bodily secretions (blood, urine, saliva, breath, and so on) positive for drugs or alcohol; c) physical evidence suggesting intoxication (odor of alcohol, slurred speech, ataxia, dysmetria, or other cerebellar findings) or behavior consistent with intoxication
8. Motor deficit: abnormal weakness in any one or more of the four extremities
9. Gait abnormality: inability to walk normally due to inadequate strength, loss of balance, or ataxia
10. Cerebellar abnormality manifested by ataxia, dysmetria, dysdiadokinesis, or other impairment of cerebellar function
11. Cranial nerve abnormality
12. Ability to read and write: determined by asking the patient to read the physician's name and subsequent ability to write that same name
13. Significant scalp hematoma
14. Severe or progressive headache
15. Coagulopathy: any impairment of normal blood clotting such as occurs in hemophilia, hepatic insufficiency, and secondary to medications (warfarin, heparin, aspirin, and so on)
16. Abnormal behavior: any inappropriate action displayed by the victim including excessive agitation, inconsolability, refusal to cooperate, lack of affective response to questions or events, and violent activity

neurologic effect, and such patients may initially appear well, only to deteriorate subsequently.

This study was designed to examine the presenting signs and symptoms among older victims of blunt head injury with and without clinically important intracranial injury and to examine injury patterns and prevalence of injury among such patients. We also compared these patterns with those found in younger patients and estimated the prevalence of occult injury among the elder cohort.

METHODS

Study Design

This study is a secondary analysis of the National Emergency X-Radiography Utilization Study (NEXUS) II head injury cohort. The methodology of NEXUS II, a multicenter, prospective, observational study, has been described in detail elsewhere.[3,4] NEXUS II was an observational study that did not mandate or direct any aspect of patient care and posed no risk to patients. These conditions qualified the study for waiver of informed consent. The Federal Office for the Protection from Research Risks, as well as the institutional review board at each site, reviewed the study protocols and methodology.

Study Setting and Population

Briefly, NEXUS II enrolled all traumatic blunt head trauma victims undergoing computed tomographic (CT) imaging of the head in the emergency departments of the 21 participating study centers. Patients without blunt trauma, including those with penetrating head trauma and those undergoing CT imaging of the head for other reasons such as a headache or suspected stroke, were not eligible for inclusion.

Study Protocol

Patients were enrolled when the examining physician ordered CT imaging. The decision to obtain the scan was made by the emergency clinicians based on their own criteria and was not directed in any way by the study. Thus, the study population consisted of consecutive blunt head trauma victims for whom CT scanning of the head was ordered. By protocol, the presence or absence of 16 specific clinical variables was documented before CT imaging was performed (Table 1). Clinicians also determined whether each patient exhibited a normal Glasgow Coma Scale score (GCS). All participating institutions agreed to enforce a rigid protocol whereby CT scanning of the head was not performed on any patient until the data collection form had been completed.

Outcome Measures

The diagnosis of intracranial injury was based solely on the final radiologic interpretation of all imaging studies, including those obtained in the inpatient setting. CT scans were interpreted independent of the study by clinical radiologists at the study sites. Intracranial injuries defined as clinically significant are listed in Table 2. Conversely, injuries that are unlikely to require any specific management and do not result in long-term adverse consequences were defined as clinically insignificant, although we recognize that they may be otherwise important to the individuals involved. While the list was developed by a consensus of experts in neurosurgery, neuroradiology, and emergency medicine, a study by Atzema et al. validates this consensus opinion.[5]

We defined occult intracranial injury as previously stated, and open, depressed, basilar, or diastatic skull fractures were as a group defined as "clinically significant skull fractures." Demographic information,

Table 2
Significant Intracranial Injuries

Clinically significant brain lesions are determined by the presence of any of the following:

1. Mass effect (sulcal effacement)
2. Signs of herniation
3. Basal cistern compression or midline shift
4. Substantial epidural or subdural hematoma (larger than 1.0 cm in width, or causing mass effect)
5. Substantial cerebral contusion (larger than 1.0 cm in diameter, or more than one site of contusion)
6. Extensive subarachnoid hemorrhage
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

including age, date and time of evaluation, gender, and race, was recorded for each patient.

Data Analysis

We constructed a subcohort of all patients aged 65 years or older and a second subcohort of all younger patients. We excluded all NEXUS cases that lacked documentation of age. We assessed the presence of any injury, as well as significant and occult injuries, in both the older and younger cohorts. We also assessed the prevalence of specific types of injury and the prevalence of the individual presenting signs and symptoms. Data are presented as raw prevalence with exact 95% confidence intervals (CIs).[6]

RESULTS

NEXUS II enrolled a total of 13,726 patients. Age information was not documented in 402 cases (3.0%), leaving 13,326 cases available for this analysis. Of these study subjects, 1,934 (14.5%) were aged 65 years or older and 11,392 (85.5%) were younger than 65 years. CT imaging detected any injury in 242 older patients (12.5%; 95% CI = 11.1% to 14.1%) and 900 younger patients (7.9%; 95% CI = 7.4% to 8.4%). Table 3 presents the prevalence of specific types of injury among these older and younger populations.

Table 4 presents the prevalence of presenting clinical findings in patients with any intracranial injury. Only 22 elder patients were believed by the examining clinician to have physical findings suggesting a skull fracture (9.1%; 95% CI = 5.8% to 13.4%), in contrast to such physical findings in 197 younger patients (21.9%; 95% CI = 19.2% to 24.7%). Older patients were less likely to appear intoxicated (6.6%), have persistent vomiting (6.2%), or experience seizure activity (3.3%) in association with their injury, but they frequently experienced suspected coagulopathy (11.6%), which was defined as any impairment in blood clotting (see Table 1), based on initial patient clinical evaluation.

We identified a clinically significant intracranial injury in 178 elder patients (9.2%; 95% CI = 8.0% to 10.6%) and 697 younger patients (6.1%; 95% CI = 5.7% to 6.6%). In this group, an occult presentation was present

Table 3
Prevalence of Specific Injuries among Older and Younger Patients with Blunt Head Injury

	Elders (*n* = 242)		Young (*n* = 900)	
Injury Type	Raw No.	% Prevalence (95% CI)	Raw No.	% Prevalence (95% CI)
Skull fractures				
Basilar	6	2.5 (0.9, 5.3)	29	3.2 (2.2, 4.6)
Complex	4	1.7 (0.5, 4.2)	43	4.8 (3.5, 6.4)
Depressed	4	1.7 (0.5, 4.2)	62	6.9 (5.3, 8.7)
Diastatic	1	0.4 (0.0, 2.3)	17	1.9 (1.1, 3.0)
Linear	1	0.4 (0.0, 2.3)	137	15.2 (12.9, 17.7)
Other	2	0.8 (0.1, 3.0)	9	1.0 (0.5, 1.9)
Bleeds				
Epidural	10	4.1 (2.0, 7.5)	118	13.1 (11.0, 15.5)
Acute subdural	86	35.5 (29.5, 41.9)	279	31.0 (28.0, 34.1)
Subacute subdural	3	1.2 (0.3, 3.6)	6	0.7 (0.2, 1.4)
Chronic subdural	8	3.3 (1.4, 6.4)	14	1.5 (0.9, 2.6)
Acute on chronic	9	3.7 (1.7, 6.9)	2	0.2 (0.0, 0.8)
Other extra-axial	10	4.1 (2.0, 7.5)	51	5.7 (4.2, 7.4)
Subarachnoid	103	42.6 (36.3, 49.1)	322	35.8 (32.6, 39.0)
Intraparenchymal	52	21.5 (16.5, 27.2)	134	14.9 (12.6, 17.4)
Intraventricular	33	13.7 (9.6, 18.6)	62	6.9 (5.3, 8.7)
Contusions/other				
Contusions	77	31.8 (26.0, 38.1)	367	40.8 (37.5, 44.1)
Focal edema	17	7.0 (4.1, 11.0)	70	7.8 (6.1, 9.7)
Diffuse edema	5	2.1 (0.7, 4.8)	63	7.0 (5.4, 8.9)
Diffuse axonal injury	2	0.8 (0.1, 3.0)	8	0.9 (0.4, 1.7)
Shift/mass effect	58	24.0 (18.7, 29.9)	225	25.0 (22.2, 28.0)
Herniation	14	5.8 (3.2, 9.5)	30	3.3 (2.3, 4.7)
Pneumocephalus	2	0.8 (0.1, 3.0)	112	12.4 (10.4, 14.8)
Other	7	2.9 (1.2, 5.9)	20	2.2 (1.4, 3.4)

Table 4
Prevalence of 16 Clinical Findings among Patients with Intracranial Injury

Finding	Elders (*n* = 242)		Young (*n* = 900)	
	Raw No.	% Prevalence (95% CI)	Raw No.	% Prevalence (95% CI)
Neurologic deficit	135	55.8 (49.3, 62.1)	525	58.3 (55.0, 61.6)
Altered alertness	125	51.7 (45.2, 58.1)	536	59.6 (56.3, 62.8)
Skull fracture	22	9.1 (5.8, 13.4)	197	21.9 (19.2, 24.7)
Any loss of consciousness	131	54.1 (47.6, 60.5)	568	63.1 (59.9, 66.3)
Prolonged loss of consciousness	47	19.4 (14.6, 25.0)	239	26.6 (23.7, 29.6)
Scalp hematoma	124	51.2 (44.8, 57.7)	410	45.6 (42.3, 48.9)
Persistent emesis	15	6.2 (3.5, 10.0)	98	10.9 (8.9, 13.1)
Coagulopathy	28	11.6 (7.8, 16.3)	32	3.6 (2.4, 5.0)
Seizure	8	3.3 (1.4, 6.4)	42	4.7 (3.4, 6.3)
Abnormal GCS	125	51.7 (45.2, 58.1)	474	52.7 (49.3, 56.0)
Intoxication	16	6.6 (3.8, 10.5)	201	22.3 (19.7, 25.2)
Headache	19	7.9 (4.8, 12.0)	118	13.1 (11.0, 15.5)

in 42 older patients (2.2%; 95% CI = 1.6% to 2.9%) and in 92 younger patients (0.8%; 95% CI = 0.7% to 1.0%). Overall, there was an occult presentation (with no evidence of clinically significant skull fracture, neurologic deficit, or altered level of consciousness) in 161 older patients, including the 42 who proved to have a significant injury (26.1%; 95% CI = 19.5% to 33.6%), and 5,070 younger patients, including the 92 with such an injury (1.8%; 95% CI = 1.5% to 2.2%).

Three elder patients with significant injury did not manifest any of the 16 criteria that clinicians commonly use in assessing head injury patients. The injuries in these patients included 1) parietal contusion with hemorrhage and edema as well as midline shift in a 66-year-old woman; 2) extensive subarachnoid hemorrhage over the left temporal bone, sylvian fissure, and right frontoparietal lobes in a 71-year-old man; and 3) extra-axial hematoma with subfalcine herniation in a 73-year-old man.

DISCUSSION

Several investigators have developed guidelines and decision instruments with the purpose of defining indications for neuroimaging in patients with mild blunt head trauma.[7] The sensitivities of decision instruments for "acute traumatic CT abnormalities" have ranged between 90% and 100%, and older age has emerged as an important high-risk variable.[8–12] Haydel et al. developed a decision rule that was 100% sensitive for "abnormal CT findings" in patients with a GCS of 15 who initially experienced loss of consciousness.[9] Age older than 60 years was highly predictive of an abnormality on CT scan and was included as one of the final criteria in the decision rule. In a Canadian derivation study, 254 patients developed "clinically important brain injury," which was defined as injuries that normally require admission to the hospital and neurologic follow-up.[13] Age 65 years or older was associated with an odds ratio of 4.1 in predicting clinically important injury but was not presented as a significant predictor of injuries requiring neurosurgical intervention.

Although previous studies have shown that advanced age is a high-risk factor for traumatic intracranial injury, investigators have typically distinguished only between acute "traumatic CT abnormality" or "acute intracranial injury" and injuries that require neurosurgical intervention.[14,15] These reports have generally not differentiated any injury from significant or occult injury as defined here. Because of their serious consequences to patients, their families, and their caregivers, we considered critical interventions, in addition to craniotomy, and chronic disability as criteria for significant injury. In addition, occult injuries are particularly important to examine as a separate cohort because they are more likely to be missed because of a benign presentation.

Only a limited number of previous studies have described critical intracranial injuries that require neurosurgical intervention in elders.[16] Nagurney et al. found a significantly greater risk of "acute traumatic injury" in the group aged 60 years or older than in the younger age group; however, advanced age was not found to be a significant risk factor for neurosurgical intervention.[17] In contrast, other investigators have found advanced age to be an independent predictor of intracranial hematomas requiring surgical evacuation following blunt head trauma.[18] In a series of patients "who talked and subsequently deteriorated into coma," Lobato et al. found that the injuries with the highest mortality rate (i.e., intradural mass lesions such as subdural hematoma and brain contusion/hematoma) occurred twice as often in patients older than 40 years as in younger individuals.[19] Our data support the conclusion that elders are at increased risk of significant intracranial injury, as we found a 50% higher prevalence than in the younger age group.

Anticoagulation therapy presents a particular risk for intracranial injury despite an initially normal presentation with a GCS of 15.[20] In addition, this therapy is a predisposing factor for injury in 33% of patients with chronic subdural hematoma, which is predominantly a disease of elders.[21] We found coagulopathy, broadly defined as any impairment of blood clotting, to be present in more than 10% of elders and in only 3% of younger patients with any intracranial injury.

The initial presentation of intracranial injury also differs between elders and younger patients. In the cohort of patients with significant intracranial injury, elders were more likely to present in occult fashion (2.2% vs. 0.8%), which suggests that the threshold for imaging should be lower in this age group. In fact, three patients were documented as having completely normal evaluations for all of the criteria in Table 1, and we do not know what motivated imaging in these cases. We suspect that many clinicians would have omitted imaging for these individuals. Persistent vomiting and headache were less likely to occur in elders with any intracranial injury in our study. This age-related difference in the incidence of vomiting and headache has also been described in patients with traumatic intracranial hematomas.[22] In patients with any intracranial injury, we found that younger adults and elders did not differ markedly with respect to the frequency of focal neurologic deficits or alteration in mental status.

On the other hand, in patients with serious injuries that potentially require surgical drainage such as subdural hematoma, Liliang et al. found that patients aged older than 75 years presented with a higher incidence of mental status changes and focal neurologic deficits and have larger hematomas when measured by the maximal thickness on CT examination.[22] Surgical outcomes and mortality did not measurably differ between the groups in this series.

Elders have worse outcomes than younger patients in terms of mortality and functional status despite comparable injuries.[23] Age older than 65 years and initial GCS have emerged as independent predictors of high mortality. Elders have a mortality rate twice that of the younger age group, even when considering only patients with mild to moderate head trauma (GCS 9–15). Poor functional outcome, defined as severe disability or persistently vegetative state, results in a rate that is almost three times higher in elders compared with younger patients. Of individuals who survive to discharge, 72% of elders experience a change in functional status requiring increased family involvement and support services.[24]

To date, validated recommendations to guide decisions about tomographic imaging in older victims of blunt trauma have not been published; there are no criteria that can be used reliably to exclude intracranial injury among these individuals. Clinicians must appreciate the increased rate of occult, serious injury that can occur following relatively minor trauma in elders. Our results have implications beyond patients who were "ill enough" to require a CT scan of the head, because we may have missed injuries that occurred among patients who did not undergo imaging. In this regard, our study concludes that occult injuries are present and clinicians must be wary when caring for older head injury victims, including patients they might not normally consider for imaging. We recommend careful and prolonged observation as well as liberal use of intracranial imaging as a reasonable approach for assessing injury potential in these patients.

LIMITATIONS

The study enrolled only patients who were selected for CT imaging at the discretion of the physician. Because we did not verify intracranial injury status for all blunt head trauma patients, it is possible that patients who did not undergo imaging might have had important intracranial injuries while exhibiting none of the risk criteria. Although NEXUS II used methods to assess the potential for such verification bias and failed to identify any missed injuries in elders, it is still possible that some injuries may have been missed. Thus, our observations likely underestimate the true prevalence of occult injury, and clinicians should consider this when caring for elder patients with head injury. In fact, this workup bias actually strengthens our results, because the patients we enrolled generally had some evidence of injury and we may have missed patients who had totally "occult" presentations.

In addition, we are unable to identify criteria that could reliably be used to detect or exclude injury in elders. NEXUS II examined a large number of reasonable criteria, but it is possible that other factors could be useful in assessing risk status. Consequently, the occult injury cases identified in this study actually represent cases with relatively benign presentations.

Finally, only a fraction of the significant intracranial injuries in our study actually required intervention, and many of these injuries did not result in adverse sequelae. In this regard, our study may overestimate the burden of missed injury and the prevalence of serious injuries that must be detected to prevent further deterioration.

CONCLUSIONS

Advanced age appears to be associated with an increased risk of intracranial injury following blunt head trauma and is an independent risk factor. Older age is also a significant risk factor for otherwise occult injury, a factor that must be considered in developing policies for selective cranial imaging. Injuries in elder patients reflect the mechanisms common in this age group such as ground-level falls, with a relatively low prevalence of physical evidence of injury and significant skull fractures.

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APPENDIX A

The following centers and investigators collaborated in this study. Principal investigator: W. Mower. Coinvestigators: J. Hoffman and M. Herbert. Steering committee: M. Herbert, J. Hoffman, W. Mower, C. Pollack, A. Wolfson, and M. Zucker. Site investigators: Boston University, Boston Medical Center (Boston, MA): N. Rathlev and G. Barest; Case Western Reserve University, MetroHealth System (Cleveland, OH): R. K. Cydulka and B. Karaman; Cooper Hospital, University Medical Center (Camden, NJ): C. Terregino, A. Nyce, and S. Ross; Emory University Medical Center (Atlanta, GA): D. Lowery and S. Tigges; Hennepin County Medical Center (Minneapolis, MN): B. Mahoney and J. Hollerman; Louisiana State University Medical Center, Charity Hospital (New Orleans, LA): M. Haydel and E. Blaudeau; Maricopa Medical Center (Phoenix, AZ): C. Pollack and M. Connell; Ohio State University Medical Center (Columbus, OH): D. R. Martin and C. Mueller; Stanford University Medical Center (Stanford, CA): S. V. Mahadevan and G. Arabit; State University of New York at Stony Brook (Stony Brook, NY): P. Viccellio and S. Fuchs; University of Calgary, Foothills Hospital (Calgary, Canada): G. Lazarenko and C. Fong; University of California, Davis, Medical Center (Sacramento, CA): J. Holmes and R. A. McFall; University of California, Irvine (Irvine, CA): J. Krawczyk; University of California, Los Angeles, Center for the Health Sciences (Los Angeles, CA): J. Hoffman and M. Zucker; University of California San Diego Medical Center Hillcrest (San Diego, CA): D. Guss and D. Meltzer; University of California, San Francisco at Fresno, University Medical Center (Fresno, CA): G. Hendey and R. Lesperance; University of Cincinnati, University Hospital (Cincinnati, OH): G. J. Fermann and H. H. Hawkins; University of Missouri, Kansas City, Truman Medical Center (Kansas City, MO): E. Westdorp and S. Go; University of Pennsylvania Medical Center (Philadelphia, PA): J. Hollander; University of Pittsburgh Medical Center (Pittsburgh, PA): A. Wolfson and J. Towers; Vanderbilt University Medical Center (Nashville, TN): V. Norton.