### Neurosurgery 1992-98

*January 1993, Volume 32, Number 1* **9** Clinical Predictors of Abnormality Disclosed by Computed Tomography after Mild Head Trauma Clinical Study

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Neurosurgery 32; 9-16, 1993

ABSTRACT: WE PROSPECTIVELY STUDIED 712 consecutive patients during a 1-year period who presented with amnesia or loss of consciousness after nonpenetrating head trauma and who had a perfect Glasgow Coma Scale score of 15. Of the 67 (9.4%) patients with acute traumatic lesions disclosed by computed tomography (CT) of the head, 2 required neurosurgical intervention and 1 died. Four factors were statistically correlated (P < 0.05) with abnormal CT findings: Older age, white race, signs of basilar skull fracture, and being either a pedestrian hit by a motor vehicle or a victim of an assault. Sex, length of antero- or retrograde amnesia, forward and reverse digit spans, object recall, focal abnormality on the general neurological exam, and subjective complaints were not statistically correlated with CT abnormality. Using step-wise discriminant function analysis, no single item or combination of items could be used to classify 95% of the patients into either the normal or abnormal CT group. Therefore, regardless of age, mechanism of injury, or clinical findings, intracranial lesions cannot be completely excluded clinically on head-trauma patients who have loss of consciousness or amnesia, even if the Glasgow Coma Scale score is 15. However, only two patients (0.3%) required neurosurgical intervention.

<u>KEY WORDS</u>: Coma; Computed tomography; Glasgow Coma Scale; Head trauma; Intracerebral hematoma; Mental status examination

The development of the Glasgow Coma Scale (GCS) <sup>(41,42)</sup> and the introduction of computed tomography (CT) have improved the management of head injury. However, criteria for emergency neuroradiological evaluation and hospital admission, decided on the basis of potential costs and benefits, have not been established. We designed this study to identify a set of clinical criteria capable of discriminating those head-trauma victims with a GCS score of 15 who are at a particular risk for having significant abnormalities disclosed by CT.

Previous studies addressing these issues were not prospective, did not specify details of the mental status examination, or combined adults and children into a single study <sup>(2,5,7,9,11,16,18,24-26,31-36,39,43,45)</sup>. We have attempted to eliminate these disadvantages by prospectively studying all adult (18 years and older) patients with loss of consciousness (LOC) or amnesia and with a GCS score of 15 who arrived in the emergency room within 24 hours of a head injury during a 1-year period. Because patients with a GCS score of 14 or less will almost invariably undergo CT, they pose less of a decision-making dilemma to the emergency room physician and were not the focus of this study.

## **METHODS**

From August 1, 1990, to July 30, 1991, we examined all patients with blunt head trauma and LOC or amnesia, regardless of duration, who arrived at Kings County Hospital, an inner city medical center and the major trauma center in the borough of Brooklyn in New York City. Patients were assigned a GCS score by the consultant, and only patients with a GCS score of 15 were included in the present report. Patients transferred from other hospitals, under 18 years of age, with no amnesia or LOC, with penetrating cranial trauma, or presenting more than 24 hours after the event were excluded.

We designed a checklist to evaluate each patient, following examples in the literature <sup>(20)</sup>. One of 12 neurologists participating in the study saw the patient in the emergency department and recorded the GCS score, age, race, sex, and mechanism of injury. Patients were asked about the presence of nausea, vomiting, headache, diplopia, blurred vision, vertigo or dizziness, tinnitus, and seizure and were questioned to ascertain the length of retrograde and posttraumatic amnesia. When available, witnesses were asked to verify and to supplement these data.

Each patient had a complete neurological examination. Learning was tested by the ability to recall the same four objects at 5 minutes. Short-term memory was assessed by forward digit span recall and concentration by reverse digit span recall <sup>(40)</sup>.

Of the 753 patients who fulfilled our entry criteria, 41 patients refused CT and were excluded from the study. The remaining 712 patients underwent noncontrast CT scans performed on a thirdgeneration CT scanner (either the GE 9800 [General Electric Medical Systems, Milwaukee, WI] or Siemens Somatom DR [Siemens Medical Systems, Inc., Iselin, NJ]). All studies were photographed, using brain (L, 40; W, 80), bone (L, 250; W, 2000), and subdural (L, 40; W, 150) windows, and were read by the neuroradiologist (MM), who did not know the details of the trauma, the patient's clinical condition, and the official institutional reading. Basilar skull fracture was diagnosed by established criteria <sup>(3)</sup>. All data were entered onto the IBM-4381 (IBM, New York, NY) and analyzed using SPSSX (SPSS Inc., Chicago, IL) by a statistician.

## RESULTS

## **Demographic features**

Of the 712 patients who fulfilled our entry criteria, 520 (73%) were male and 192 (27%) were female (Table 1). Ages ranged from 18 to 90, with a mean  $\pm$  SD of 35.6  $\pm$  14.1 years. There were 152 (21%) whites, 463 (65%) blacks, 69 (10%) Hispanics, and

28 (4%) members of other racial groups. Traffic accidents (n = 400) and assaults (n = 218) were the most common causes of injury.

#### **Computed tomographic findings**

There were 67 patients (9.4%) with significant abnormalities demonstrated by CT (Table 2). Linear skull fracture and soft tissue swelling in the absence of other findings were not included in this category. Thirty-two of the 67 patients (48%) with abnormal CT scans had multiple abnormalities.

# Factors correlated with abnormalities demonstrated by computed tomography

Four factors were statistically correlated with abnormal CT scans: Older age, white race, signs of basilar skull fracture, and certain mechanisms of injury. The mean age of patients with a normal CT scan,  $34.8 \pm 13.5$  years, was significantly lower than those with an abnormal CT scan,  $43.1 \pm 17.0$  years (P < 0.0005, two-tailed *t*-test). Whites also had a significantly higher incidence of abnormalities disclosed by CT (P < 0.02, two-tailed *t*-test). Of the 25 patients with clinical evidence of basilar skull fracture, 8 had an abnormal CT scan (P < 0.0001, *t*-test with Pearson correction). CT demonstrated abnormality was also more common in cases of assault and for pedestrians struck by motor vehicles (P < 0.02, two-tailed *t*-test).

## Factors not correlated with abnormal computed tomographic scans

Subjective complaints after acute head trauma were very common (Table 3). Most patients complained of headache. However, none of the subjective complaints studied was statistically correlated with the presence of abnormal CT scans (P > 0.05 for each, two-tailed *t*-test). Length of retrograde and post-traumatic amnesia were also not statistically correlated with abnormal CT findings (P = 0.8 and 0.40, two-tailed *t*-test, respectively). Focal abnormalities on the general neurological examination were present in 26 patients, 22 of whom had a normal CT scan (P > 0.05).

The mean forward and reverse digit span and object recall for patients with normal CT scans (6.1  $\pm$ 1.5,  $3.6 \pm 1.5$ , and  $2.1 \pm 1.3$ , respectively) was not significantly greater than for those with abnormal CT scans  $(6.1 \pm 1.8, 3.6 \pm 1.6, \text{ and } 2.1 \pm 1.4,$ respectively), P > 0.05 for each (Table 4). In some cases, performance on our mental status testing was entirely normal, including some of the patients with the most significant intracranial lesions disclosed by CT, i.e., those with intracranial hematomas, intraventricular hemorrhage, and depressed skull fracture (Table 5). Of note, only three patients had a very significant adverse outcome (one death, two requiring craniotomy). Using step-wise discriminant function analysis, no single item or combination of items could be used to classify 95% of patients into either the normal or abnormal CT group.

#### Significant case reports

#### Patient 71

A 49-year-old man was found beside his bicycle with his wallet missing and significant external bruises including a large hematoma over the right eye. At arrival at the emergency department, he was alert, oriented, and able to do simple calculations. His forward and reverse digit span tests were 7 and 4, respectively. His general neurological examination was normal; specifically, there was no facial weakness. A fracture of the right clavicle and several rib fractures were diagnosed. A peritoneal lavage disclosed nothing abnormal. During the next several hours, he became more lethargic, agitated, and confused; intravenous administration of lorazepam was necessary. A CT scan revealed a left temporal contusion and right-side subarachnoid hemorrhage. Six hours after arrival, a mild left central facial paresis was noted. Craniotomy was performed that day for debridement of the contusion. The patient did well postoperatively. Neuropsychological testing demonstrated comprehension deficits, paraphasic errors, and dysnomia--all consistent with Wernicke aphasia. He was discharged to his home on hospital Day 24.

#### Patient 297

A 41-year-old alcoholic man was assaulted late one evening but went home without seeking medical attention. When he awakened several hours later with headache, he was brought to the hospital. He had several minutes of amnesia and complained of headache, nausea, three episodes of vomiting, and slight dizziness. Despite an alcohol level of 108 mg/dL, he was alert and oriented. His forward and reverse digit span tests were 4 and 3, respectively. His general neurological examination was normal. Head CT scan demonstrated an acute right subdural hematoma. He underwent successful craniotomy and removal of the hematoma and was discharged to his home on hospital Day 14.

#### Patient 530

A 79-year-old, unrestrained man fell asleep while driving a car and struck a pole. At his arrival in the emergency room, he was awake, oriented, and complaining only of mild headache. His medical history was significant for diabetes mellitus, hypertension, congestive heart failure, chronic renal insufficiency, and previous myocardial infarction. He was able to repeat 7 digits forward and 3 digits backward. Except for presbycusis and bilateral periorbital ecchymosis, his examination was normal. X-rays failed to reveal any fractures. Head CT scan demonstrated an intracranial air-fluid level anterior to the left frontal lobe, a left subdural hematoma. pneumocephalus, and cerebral atrophy. He began receiving intravenous antibiotics. A repeat CT scan on hospital Day 4 showed resolution of the intracranial lesions. On hospital Day 5, he became hypotensive, bradycardic, and lethargic; he was intubated. Cardiac isoenzymes were consistent with myocardial infarction. He developed recurrent episodes of sustained ventricular tachycardia that were unresponsive to medical therapy and pacemaker

overdrive. On hospital Day 8, he became hypotensive and died.

## DISCUSSION

Indications for neuroimaging in acute trauma have not been established. Different study populations among previous reports make generalization difficult (Table 6). Some have recommended that all patients undergo CT, even in the absence of LOC and neurological deficit <sup>(18)</sup>, or if there is progressive headache, vomiting, serious facial injury, or multiple trauma <sup>(23)</sup>. Others take the mechanism of injury into account as well <sup>(22,38)</sup>. Some require LOC, amnesia, signs of possible depressed skull fracture, or focal neurological deficits <sup>(24,28,39)</sup>.

Because 5% of patients with a GCS score of 13 to 15 may eventually require neurosurgery <sup>(39)</sup>, we searched for other clinical and epidemiological factors that may provide a more sensitive and specific predictor of CT abnormality. Patients with a GCS score of 14 or less should ideally undergo CT whenever possible. For those with a GCS score of 15, clinical management is less clear and has not been adequately studied. One report included 89 patients with a GCS score of 15 who had extradural hematomas <sup>(37)</sup>. Despite analysis of historical and epidemiological factors, subjective complaints, and mental status examination, we found no item or combination of items that could alter the treatment algorithm for head trauma patients with a GCS score of 15 and that would provide an accurate prediction of CT normality or abnormality.

Of the epidemiological descriptors studied, age was most significantly (P < 0.0005) associated with an abnormal CT scan. Increased mortality and morbidity with increasing age is well documented (1, <sup>6,13,15,30</sup> and confirmed by our study. Although men may be 3 to 4 times more likely to suffer lethal injury  $^{(8,44)}$ , we did not observe any difference in the incidence of CT abnormality between the sexes. As in previous studies of head trauma in the United States, traffic accidents accounted for about half the cases (6, <sup>12,14,17,32,33,45)</sup>. Victims of assault and pedestrians struck by a motor vehicle had an abnormal CT more often. One report found that being hit with a blunt object (e.g., baseball bat) was less often associated with intracranial abnormality than being assaulted with fists and feet (10). This is not confirmed by our study where assault with a blunt object was twice as likely to cause CT abnormality (17% versus 9%). The higher incidence of CT disclosed abnormality in white patients (P = 0.03, two-tailed *t*-test) likely represents selection bias; less severely injured white patients may have sought care at a site other than a city hospital. Other studies have found the incidence of head trauma in major cities to be highest for minority populations (28,37).

A recent British editorial recommended hospital admission for all patients with a GCS score of less than 15, signs of basilar skull fracture, seizure, focal neurological signs, persistent headache or vomiting, and skull fracture <sup>(27)</sup>. Because CT is more readily available in the United States, patients with linear skull fractures, a GCS score of 15, and no intracranial

abnormalities disclosed by CT can be safely discharged with appropriate instructions and followup <sup>(21)</sup>. Admission and observation is recommended for all patients with intracranial hematomas. The high frequency of intracranial bleeding in our study population of patients with mild head trauma and a GCS score of 15 has not been previously documented. Nonetheless, only three had a very significant adverse outcome. However, Patient 71 would have undergone CT anyway because his mental status deteriorated and he developed a left facial paresis; Patient 297 would have undergone CT because of progressive headache, especially because he was alcoholic and at higher risk for intracranial hematoma; and Patient 530 died of multiple medical complications despite radiological evidence of resolution of his intracranial lesions.

If the clinician has a heightened level of suspicion, it is appropriate to perform a head CT scan even if the patient is fully oriented, has a GCS score of 15, and normal performance on bedside neuropsychological testing. Criteria for CT in patients without LOC or amnesia remain to be determined by a prospective study.

Although several facets of the neurological and mental status examinations were statistically correlated with CT abnormality in our study, a normal clinical and mental status examination neither excluded significant head injury nor eliminated the role of neuroimaging. Patients with LOC or amnesia after head trauma may harbor intracranial lesions, even if they have a GCS score of 15. However, the chance of requiring neurosurgical intervention is small.

#### ACKNOWLEDGMENTS

The authors wish to thank Matthew J. Avitable, Ph.D. and Richard Lechtenberg, M.D. for performing the statistical analyses of our data. We also acknowledge with appreciation the helpful suggestions and contributions of Drs. Roger Q. Cracco, Mahendra Somasundaram, Paul Cooper, Jeffrey Benjamin, Ronald Lazar, Gwendolyn Hotson, Luis Figueroa, Katie Henry, Carrie Landess, Antoin Munirji, Moquit Usman, Michael Goodman, and Aristotles Pena. We are also indebted to research assistants Melanie Sinatra and Ian Cole. The cooperation of the residents in the departments of neurology, neurosurgery, radiology, and trauma surgery is also appreciated. Financial assistance for the research assistants and for expenses related to presenting the article were provided by New Medico (Lynn, MA) and SUNY Health Science Center at Brooklyn (Brooklyn, NY).

Presented in part at the 41st Annual Meeting of the Congress of Neurological Surgeons, Orlando, Florida, 1991.

Received, February 11, 1992. Accepted, July 7, 1992. Reprint requests: Joseph S. Jeret, M.D., 3126 Kings Highway, Suite 2, Brooklyn, NY 11234.

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## **COMMENTS**

The management of mild head injury has been an area of some controversy because of an absence of established guidelines. Although the vast majority of patients with mild head injury go on to make uneventful recoveries, a few patients deteriorate and become neurologically devastated or die. The incidence of such deterioration is very low (i.e., less than 0.02%) in other reported studies and 0.4% in the present report. Nevertheless, in the current medicolegal climate in the United States, there is zero tolerance for such an eventuality. The only effective way to avoid missing such cases is to obtain computed tomographic (CT) scans on every patient with a head injury. Even in a very highly developed and wealthy medical system, such as in the United States, this is rather expensive and not always practical. It is important therefore to try to identify subgroups of patients who are at particular risk for developing intracranial masses and to obtain CT scans on them. Conversely, patients who do not meet these criteria could be managed with clinical observation alone. However, this goal has yet to be achieved.

This article reports an epidemiological study that is well designed and effectively presented. The study demonstrates that of 712 consecutive patients with a Glasgow Coma Scale of 15 who presented to the emergency room with amnesia or loss of consciousness after closed-head injury, 67 (9.4%) had an abnormality on the initial CT scan. Of these, only two required neurosurgical intervention and one died. At the most, this represents a 0.4% incidence of surgical mass lesions in this group of patients. As the authors have noted in their discussion, other reports have suggested that adults with no skull fracture and preserved orientation did not need CT scans because the chance of significant intracranial hematomas was less than 0.02%. Although this study also demonstrates that it is not easy to predict which patients will have CT abnormalities, it confirmed the clinical impression that the vast majority of patients who meet this description will go on to make an uneventful recovery. In the final analysis, the issue rests on the question of why a CT scan is needed. If its purpose is to detect mass lesions because they cause the patient to deteriorate, this does not seem to be a very cost effective or practical way to deal with this group of patients (yield of only 0.4%). A CT scan could certainly be justified if the clinician has a heightened level of suspicion for any reason, or if the scan is needed for academic or research purposes. Having been surprised on more than one occasion by rather significant CT scan findings in the presence of a relatively benign clinical presentation, I believe that in the perfect world where there are no practical or financial constraints, scanning every patient with a mild head injury could be justified. However, this

study should not be construed to indicate that routine CT scanning in this subset of patients is a mandatory or a high-yield activity.

#### **Raj K. Narayan** *Houston, Texas*

This well-executed, prospective study addresses the question of how frequently abnormalities are found on a head CT scan, and whether these lesions can be correlated with certain demographic or clinical data in adult patients who suffered a head injury with loss of consciousness and/or amnesia, but who had a normal Glasgow Coma Scale score. In 712 consecutive patients, the incidence of post-traumatic lesions was 9.4% and these lesions could be correlated with only a few of the many factors examined. In fact, it is impossible to predict which patients will and which will not have CT abnormalities. Does this now mean that every patient fitting the entry criteria for this study needs to be scanned? Absolutely not! This study was not designed to assess the effect of using CT scans on outcome in these patients, and it also does not address costs. The only patient who died did so despite having had a head CT, and a scan is obviously not insurance against an unfavorable outcome. Moreover, of the only two patients (less than 0.3%) who underwent neurosurgical intervention, one deteriorated before CT scanning and he would have been scanned (and undergone surgery) anyway, whereas the other might well have ended up with a chronic subdural hematoma weeks later. On top of this, most neurosurgeons have a patient, or know of one, with a normal CT scan who still needed to be taken to the operating room emergently hours or days later. As the authors noted in the introduction, "criteria for emergency neuroradiological evaluations and hospital admission, decided on the basis of potential costs and benefits, have not been established." Such criteria can probably only be established in a randomized study, and considering the enormous financial implications of our decisions, based on sheer numbers, such a study might well be a worthwhile undertaking. Until then, however, deciding "to scan or not to scan," or "to admit or not to admit" remains more art than science, with most physicians probably erring "to stay on the safe side."

## J. Paul Muizelaar

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Descriptor	Total Patients		Abnormal Computed Tomographic Scan		Р
	No.	%	No.	%	
Age					<0.0005
18–30 yr	320	45	19	6	
31-40 yr	190	27	15	8	
41–50 yr	105	15	13	12	
51–60 ýr	50	7	7	14	
>60 yr	47	7	13	28	
Sex					NS
Male	520	73	52	10	
Female	192	27	15	8	
Race					0.02
White	152	21	21	14	
Black	463	65	38	8	
Hispanic	69	10	2	3	
Other	28	4	6	21	
Mechanism of injury					0.02
Traffic accident	400	56	35	9	
Pedestrian struck	100	14	18	18	
Motor vehicle occupant	270	38	15	6	
Motorcycle or bicycle	30	4	2	7	
Assault	218	31	25	12	
Fists and feet only	81	11	7	9	
Blunt object	87	12	14	16	
Both or unknown	50	7	4	8	
Fall	63	9	4	6	
Other	31	4	4	13	

Table 1. Demographic Features

Computed Tomography Finding	Isolated	In Combination	Total
Epidural hematoma	0	2	2
Subdural hematoma	2	7	9
Intracerebral hematoma	2	5	7
Cerebellar hematoma	1	0	1
Contusion	10	7	17
Intraventricular hemor- rhage	1	4	5
Subarachnoid hemor- rhage	7	13	20
Basilar skull fracture or pneumocephalus	19	5	24
Depressed skull frac- ture	2	2	4
Diastatic fracture	1	0	1
Total	45	45	90

Table 2. Abnormalities Encountered by Computed

 Tomography

Descriptor	Total P	atients	Abnormal Computed Tomographic Scan		
	No.	%	No.	%	
Headache	403	58	32	8	
Dizziness or vertigo	157	23	10	6	
Nausea	102	15	13	13	
Blurred vision	86	13	7	8	
Vomiting	51	7	8	16	
Tinnitus	36	5	6	17	
Diplopia	19	3	0	0	

<sup>a</sup> There were 22 patients who were excluded from the analysis because of a language barrier or refusal to cooperate with questioning.

Table 3. Subjective Complaints<sup>a</sup>

Descriptor	Total Patients		Abnormal Tomograj	Р	
	No.	%	No.	%	
Forward dig	git span				0.55
8+	52	7	5	10	
7	227	32	23	10	
6	146	20	11	8	
5	102	14	7	7	
4	32	5	4	13	
3	17	3	1	6	
2	2	0	0	0	
0	10	2	2	20	
Reverse digit span					
7+	17	2	3	18	
6	49	7	4	8	
5	81	11	5	6	
4	134	19	11	8	
3	210	29	22	10	
2	48	7	3	6	
0	39	6	4	10	
Object reca	all				0.73
4	89	15	9	10	
3	177	29	17	10	
2	135	22	7	5	
1	97	16	6	6	
0	105	17	11	10	

Table 4. Mental Status Testing

Patient	Age	Sex	Accident	Fwd	Rev	Obj	Computed Tomographic Results
29	40	м	Assault	6	0	2	Contusion
35	71	м	Ped MVA	3	2	0	SAH + IVH
71	49	м	Assault	7	4	2	Contusion + SAH (had crani-
							otomy)
92	63	F	Ped MVA	4	2	0	ICH + SDH + SAH
177	25	м	Assault	7	4	3	Cerebellar hematoma
211	43	м	Ped MVA	_	—		Dep
214	47	м	Ped MVA	_	_		ICH + SAH
226	36	м	Driver	7	3	4	ICH + SAH
237	30	м	Assault	7	4	1	Contusion + SAH
257	54	м	Assault	8	4	4	Contusion
281	32	м	Assault	7	3	1	SDH + Dep
292	81	м	Ped MVA	7	3	3	SDH + ICH + SAH
297	41	м	Assault	4	3	0	SDH (had craniotomy)
331	78	F	Ped MVA	7	4	0	IVH + SAH
349	57	м	Driver	6	2	0	IVH + SAH
379	24	м	Driver	7	3	1	Contusion
403	29	м	Ped MVA	5	4	2	EDH + Contusion
407	52	м	Assault	7	3	1	Contusion + SAH
432	27	м	Fr seat	5	3	3	IVH + Bas
438	47	м	Assault	6	6		Contusion + Bas
461	38	F	Ped MVA	9	7	4	Contusion
489	34	м	Assault	7	5	3	Contusion
510	40	м	Ped MVA	7	6	4	ICH + SAH
530	78	м	Driver	7	3	3	SDH + Pne + IA/F (died)
572	62	м	Assault	7	3	0	SDH + Contusion + SAH
615	36	м	Assault				Contusion
623	75	F	Fr seat	7	3	1	Contusion
635	46	м	Ped MVA	5	3	2	IVH
651	41	м	Assault	4	3	1	EDH + SDH + SAH + Contusion Bas + Pne
668	28	м	Fr seat	9	_	_	ICH
700	29	F	Driver	7	3	2	Contusion
727	20	м	Assault	7	4	3	Contusion
742	56	м	Fr seat				SDH
770	44	м	Driver	7	5	3	Contusion
804	45	F	Fall	6	4		Dep
815	41	м	Assault	6	3	3	Dep + Pne

<sup>a</sup> Fwd-Rev-Obj, Forward digit span-Reverse digit span-Object recall; —, Not tested; Fr seat, Front seat of motor vehicle; Ped MVA, Pedestrian struck by vehicle; Bas, Basilar skull fracture; Dep, Depressed skull fracture; Pne, Pneumocephalus; SAH, Subarachnoid hemorrhage; IVH, Intraventricular hemorrhage; ICH, Intracerebral hematoma; SDH, Subdural hematoma; EDH, Epidural hematoma; IA/F, Intraceranial air-fluid level.

Table 5. Features of Patients with Most Significant Abnormality Demonstrated by Computed Tomography<sup>a</sup>

Series (Ref. No.)	Population	Patients	Computed Tomography	Abnormal	%
Paxton and Ambrose, 1974 (29)	Selected head trauma <sup>a</sup>	NS	99	72	73
Levander et al., 1975 (19)	Selected head trauma*	NS	70	29	41
Dublin et al., 1977 (5)	Selected head trauma <sup>a</sup>	620	200	112	56
French and Dublin, 1977 (9)	Alert + normal exam	NS	85	11	13
	Alert + focal deficit	NS	14	7	50
Koo and LaRoque, 1977 (16)	Head trauma <sup>a</sup>	N5	457	165	36
Zimmerman et al., 1978 (45)	Selected head trauma	N\$	286	167	58
Rimel et al., 1981 (32)	Mild trauma + GCS ≥13	538	32	0	0
Dacey et al., 1986 (4)	GCS = 13-15	610	68	23	34
Feuerman et al., 1988 (7)	Head trauma admissions	373	129	53	41
	GCS = 15	236	59	20	34
	GCS = 14	103	49	20	41
	GCS = 13	34	21	13	62
Present study	Amnesia or LOC + GCS = 15	759	714	70	10

Table 6. Previous Studies of Abnormality Demonstrated by Computed Tomography after Mild Trauma