Computed Tomography of Craniocerebral Injury in the Abused Child[1]

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Computed tomography (CT) was performed in 26 infants and children with craniocerebral trauma related to abuse during a 41-month period. The pattern of brain injury differed from that seen in the nonabused traumatized infant or child. Parieto-occipital acute interhemispheric subdural hematoma (AIHSH) with associated parenchymal injury was the most frequent finding (58%). Follow-up by CT in patients with AIHSH demonstrated infarction in half and cerebral atrophy in all.

INDEX TERMS: Children, injuries • Computed tomography, head, 1 [0].1211 • Head, injuries • Meninges, hemorrhage • Skull, fractures, 1 [0].410 • (Skull and contents, trauma X [battered child], 1 [0].419) • (Skeletal system, trauma X [battered child], 4 [0].4195)

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CHILD ABUSE is a major sociological problem and often a medical diagnostic one as well. Unsuspected cerebral injury, most often in the form of acute subdural hematoma (1, 2), is the most common cause of death and disability. Factors which make diagnosis difficult include the absence of a history of trauma, a vague clinical presentation, and, frequently, the paradox of significant intracranial bleeding without external signs of trauma to the head and face (3).

The importance of computed tomography (CT) in the diagnosis and management of craniocerebral trauma is well established (4). In the present paper, CT findings in 26 abused children are reviewed. The finding of parieto-occipital acute interhemispheric subdural hematoma (AIHSH) in the abused child has not been previously described, to our knowledge. The type of intracranial changes demonstrated on CT depend on the form of abuse.

MATERIAL AND METHOD

CT was performed on 26 abused children with acute head injuries over a 41-month period. These patients represented 13% of the 198 cases of acute head injury in children under 18 examined by CT at our hospital in the same period. The diagnosis of abuse was based on a combination of the following: admitted abuse; evidence of bruises, fractures, retinal hemorrhages, or repeated trauma; and the findings of social workers, psychologists, and court employees.

All injuries were clinically evaluated and assigned a grade (TABLE I). CT was performed as part of the initial diagnostic procedure, using an EMI Mark I head scanner with a waterbag. Eighteen patients had repeated CT during or after hospitalization; all were clinically re-evaluated both prior to and after discharge. Autopsy was obtained in 3 of 4 children who died and the brain sectioned to facilitate comparison.

TABLE I: GRADED CLINICAL CLASSIFICATION OF HEAD INJURY

1	= Minimal to zero disturbance of consciousness
2	= Minimal to moderate disturbance of consciousness with or without a focal neurological deficit
3	= Significant disturbance of consciousness with or without a focal neurological deficit
4	= Comatose, with a pain response
	A = Absence of focal neurological deficit
	B = Presence of focal neurological deficit

RESULTS

Our patients ranged in age from 3 months to 12 years. Twenty-one (81%) were 2 years old or younger; 15 (58%) were boys. On admission, 22 (85%) had Clinical Grade 3 or 4 brain injury (TABLE I). CT was performed on all 26 children initially and on 18 (69%) subsequently. Skull radiographs were obtained in 25 (96%). Calvarial fractures were seen in 6. TABLE II gives the clinical, radiographic, and CT findings at initial presentation and post-discharge follow-up.

Six patients had variable CT findings: 1 had an intracerebral hematoma; 1 had multiple contusions; 1 had bilateral cerebral swelling and subsequently died; 2 had at-

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rophy consistent with prior trauma; and 1 was normal. Eight children had skin bruises and 2 had fractures of the long bones or ribs.

CT showed acute subdural hematoma in 17 children (65%); in 15 (58%), it was located in the posterior (parieto-occipital) portion of the interhemispheric fissure on either side of the falx (Figs. 1 and 2, A). Four out of 15 patients had emergency subdural taps prior to CT, with removal of up to 50 ml of bloody fluid. In 2 patients, AIHSH was confirmed arteriographically; in 2, it was drained surgically following CT. All 15 patients with AIHSH also showed abnormality of the cerebral parenchyma; 3 had areas of decreased density in the parieto-occipital region, consistent with ischemic infarction, while the remaining 12 showed isodense swelling of either the occipital region (4 patients), one cerebral hemisphere (3 patients), or both hemispheres (5 patients).

Of the 15 children with AIHSH, all but one survived. Thirteen were followed up clinically and 12 others by CT as well. One death occurred in a child who exhibited massive bilateral cerebral edema two days after the finding of AIHSH. Both AIHSH and the massive cerebral swelling, demonstrated on repeated CT immediately before death, were confirmed at autopsy. Atrophic changes in the form of enlargement of sulci, ventricles, or both, were found on follow-up in all patients. The changes occurred in both cerebral hemispheres in 9 (more severely on one side in 3) and were unilateral in 3. Cerebral infarction was present in addition to atrophy in 6 of 12 patients (50%) (Fig. 2, B). Of 13 patients followed up clinically, 5 show no current evidence of neurological deficit. The 2 patients with the most severe outcomes are blind, have spastic quadriplegia, and show marked mental retardation. One patient is blind and hemiparetic; 2 have homonymous hemianopsia and hemiparesis; 2 have homonymous hemianopsia; and 1 has hemiparesis.

Two patients of 6 and 12 years, both of whom died, had an acute subdural hematoma in a location other than the

TABLE II: SUMMARY OF CLINICAL AND CT FINDINGS IN 26 ABUSED CHILDREN

				Initial Findings								Outcome		
				Fracture									
Patient	Age	Sex	Clinical Grade	Skull	Other	Bruise	Retinal Hemorrhage	Neurological Findings*	CT Findings†	Procedure‡	Clinical Grade	Neurological Deficit	CT Findings†
P.P.	3 mos.	F	3B	–	–	–	+	S, HP	AIHSH, OI	T	1A	—	UI, UA
A.C.	4 mos.	M	4	–	–	–	+	—	CSH	T	1A	—	Residual hygroma
S.M.	5 mos.	M	3A	–	–	–	+	S, HP	AIHSH, BS	T	2	Vegetative	BI, BA
T.H.	5 mos.	F	2A	+	+	–	–	—	Normal	—	1A	—	O
T.B.	6 mos.	F	4	–	–	–	+	S	AIHSH, BI	—	1B	H.H., H.P.	UI, BA
K.H.	7 mos.	F	4B	–	–	–	–	S, HP	Contusions	—	1B	H.P.	Resolving
S.B.	7 mos.	M	3A	+	–	+	+	S, QP	AIHSH, UOS	T	2	Vegetative	O
S.U.	8 mos.	M	3A	–	–	–	+	—	AIHSH, BS	—	1A	—	BA
M.H.	9 mos.	M	1B	+	–	–	–	HP	ICH	OP	1B	H.P.	Encephalomalacia
G.T.	11 mos.	M	4	–	–	–	+	—	AIHSH, BOS	T, A	Died	O	O
I.M.	1 yr.	M	3B	–	–	–	+	HP	AIHSH, UOS		1B	H.P.	UI, UA
J.B.	1 yr.	M	3B	+	–	–	–	S, HP	Atrophy	—	1A	—	O
M.F.	1 yr.	F	2A	–	–	+	+	S	Atrophy	—	1A	—	Normal
J.C.	13 mos.	M	3B	+	–	+	–	S, HP	ASH	T	1A	—	Normal
J.M.	15 mos.	M	4B	–	–	–	+	HP	AIHSH, BS	—	1B	Blind, H.P.	BA
R.T.[1]	15 mos.	M	3B	+	–	–	+	S, HP	AIHSH, BS	—	1A	—	BA
M.P.	16 mos.	M	2B	–	–	–	+	S, HP	AIHSH, BS	OP	1A	—	BA
Y.D.	18 mos.	F	4B	–	–	+	+	HP	AIHSH, OI	—	1B	H.H., H.P.	UI, BA
A.E.	18 mos.	F	4	–	–	–	–	QP	BS	A	Died	O	O
E.J.	2 yrs.	M	3A	–	–	+	–	—	AIHSH, UOS	—	O	O	O
O.D.	2 yrs.	M	3B	–	–	–	–	HP	AIHSH, US	—	1A	—	BA
L.F.	3 yrs.	F	3B	–	–	–	+	HP	AIHSH, US	—	1B	H.H.	BA
C.S.[1]	4 yrs.	F	4B	–	+	+	+	S, HP	AIHSH, US	OP	1B	H.H.	UI, UA
A.C.	5 yrs.	M	3B	–	–	+	+	S, A	ASH	OP	1A	—	O
A.L.	6 yrs.	F	4	–	–	+	+	—	AS	A	Died	O	O
S.O.	12 yrs.	F	4	0	–	–	0	—	AS	OP	Died	O	O

[1]= arteriographic demonstration of subdural hematoma
0 = no information available
* S = seizures
HP = hemiparesis
QP = quadriparesis
A = aphasia
HH = homonymous hemianopsia
† AIHSH = acute interhemispheric subdural hematoma
ASH = acute subdural hygroma
AS = acute subdural
ICH = intracerebral hematoma

CSH = chronic subdural hygroma
O = occipital
B = bilateral cerebral hemispheres
U = unilateral cerebral hemisphere
I = infarct
S = swelling
A = atrophy
‡T = tap
OP = operation
A = autopsy

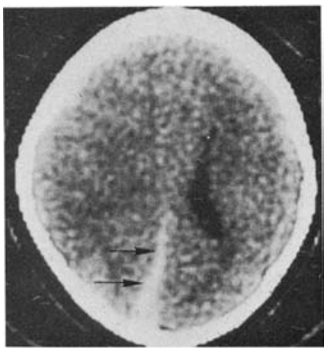

Fig. 1. A 3-year-old girl with obtusion and unilateral flaccidity after an alleged fall. CT without intravenous contrast material shows a right parieto-occipital AIHSH (arrows). The right lateral ventricle is obliterated. Following discharge, left homonymous hemianopsia developed.

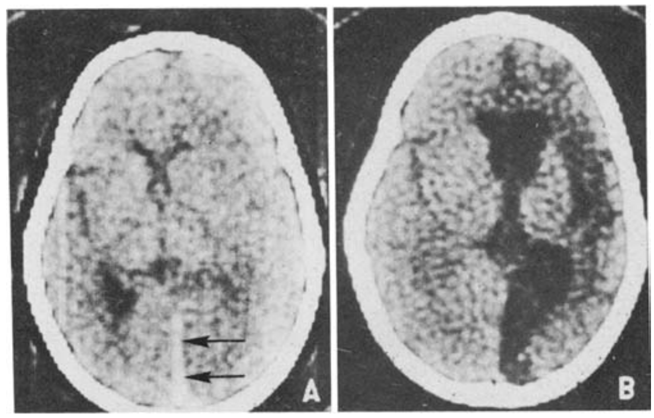

Fig. 2. A 4-year-old girl seen after an alleged fall. On admission, she was comatose with only a pain response. Bilateral retinal hemorrhage, focal seizures, right flaccidity, and old bruises were seen. Radiographs revealed a healing fracture of the humerus, but none of the calvaria.

A. CT scan without contrast material taken on admission shows a left AIHSH (arrows) and obliteration of the left occipital horn, with compression and a left-to-right shift of the left lateral ventricle.

B. CT scan 16 months later shows infarction of the left medial occipital and peri-sylvian cortex, left lateral ventricular enlargement, and displacement of the midline to the left. The residual neurological deficit was limited to right homonymous hemianopsia.

interhemispheric space. One ranged over the convexity, while the other was both supra- and infratentorial. Three patients had subdural hygromas (acute in 2, chronic in 1). CT failed to detect the acute subdural hygroma in 1 patient, due to a lack of vertex sections; however, it was found and evacuated during the insertion of a subarachnoid bolt for the monitoring of intracranial pressure. The other two hygromas were confirmed surgically.

DISCUSSION

The incidence of child abuse in the form of battering or shaking is estimated at between 200,000 to 250,000 cases a year in the United States, with 30,000 to 37,500 serious injuries (5). Most victims are under age 2 (6) and approximately half are likely to be subjected to more than one episode (7). There is a significant risk of death (5–25%) (8) and a high risk of mental retardation, psychological impairment, and neurological deficit (3, 9, 10). While psychological trauma is the outstanding component of abuse, intracranial injury is the most important form of physical trauma (1, 2), accounting for the greatest number of deaths. It is probably also the most significant determinant of future mental retardation (2, 3).

CT has made possible for the first time the rapid, accurate assessment of head injury in the abused child. Parieto-occipital AIHSH was identified by CT in 15 of 26 patients (58%) (Figs. 1 and 2, A) at the site of drainage of the cerebral veins attached to the superior sagittal sinus. Ommaya and Yarnell (11) have experimented with whiplash injury in primates and found the formation of subdural hematoma to be related to medial veins being torn from their site of attachment to the falx. The infant is highly vulnerable to whiplash, due to the relative disproportion between the large head and the weak supporting muscles of the neck (3, 6). Caffey (3) has stated that: "The heavy infantile head with its soft brain, so poorly supported by normally weak cervical muscles, fulcrumed on the atlas through the occipital condyles and pivoted on the axis is highly vulnerable to many kinds of whiplash stresses on the head such as shaking, jolting and jerking, especially when they are repeated during long periods. Special lacerating stresses are thus applied to the cerebral bridging veins at the fixed sites of their attachments to the walls of the sagittal sinuses." His statement is supported by the clinical and radiographic findings in TABLE II.

Skull fractures were infrequent (13%) in patients with AIHSH, whereas fractures were found in 50% of patients of the same age who suffered trauma unrelated to abuse. Eighty per cent of patients with AIHSH showed evidence of retinal hemorrhage, a relatively frequent ocular manifestation of whiplash (12). In 10 of 15 patients with interhemispheric subdural hematoma, the parent or guardian subsequently admitted to having shaken the child.

Follow-up CT performed in patients with AIHSH indicated significant cerebral injury (Fig. 2, B). There was a 100% incidence of cerebral atrophy and a 50% incidence of cerebral infarction in this series. Only 5 of 13 follow-up patients were without neurological deficit; whether the same held true for psychological deficit was not determined. The nature of the deficit (hemi- or quadriplegia) and the ocular defect were consistent with parenchymal injury as demonstrated by CT. Homonymous hemianopsia contralateral to both occipital infarction and AIHSH indicated a relationship between the torn veins, parenchymal damage, and subsequent occipital lobe infarction. The pa-

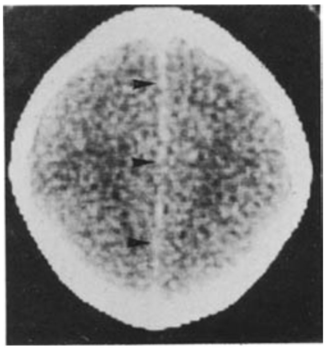

Fig. 3. Interhemispheric subarachnoid hemorrhage (falx sign) in a 5-year-old girl who became unconscious immediately after being struck by an automobile. CT scan without contrast material shows a thin stripe of blood density between the cerebral hemispheres (arrowheads).

renchymal damage may have been due to venous infarction secondary to vascular disruption, cortical contusion with the development of edema, or focal loss of autoregulation with vasodilatation and cerebral swelling; or secondary to posterior cerebral artery occlusion from transtentorial herniation.

Interhemispheric subdural hematoma should not be confused with interhemispheric subarachnoid hemorrhage (falx sign), also seen in pediatric head injuries (13). In the latter, the dense stripe of blood in the falx sign is thinner, often extending the entire distance of the fissure (Figs. 1, 2, A, and 3). In some patients, small amounts of subdural blood extend around the occipital pole to the lateral cerebral convexity; however, the amount of blood over the convexity appears to be considerably less than in the fissure. We observed AIHSH due to other causes in only 1 of our pediatric patients: a 6-year-old hemophiliac beaten by other children.

Retinal hemorrhage, the ocular manifestation of whiplash, is not presently detectable by CT. In 1 patient, massive retinal hemorrhage of the left eye was suspected. Follow-up by CT two months later showed the left eye to be smaller than the right; the patient is now blind in the left eye. Another patient with an 11.5-year history of abuse demonstrated phthisis bulbi of the right eye.

Determining the cause of trauma was difficult because oral histories were unreliable; no parent or parent-surrogate who brought a child to the hospital gave an initial report of abuse. In 17 cases, the child was said to have fallen hours or days before; in 9, to have become obtunded or to have vomited repeatedly without cause; while in 3, a physician had referred the child, not for evaluation of abuse, but with the diagnosis of meningitis (2 patients) and diencephalic tumor (1 patient).

Because approximately 50% of abused children are victims of repeated episodes, acute traumatic CT findings may be superimposed on those of prior injury. This probably accounts for the finding of atrophy in 2 patients who were still obtunded.

CONCLUSION

The most frequent CT finding in the abused child with acute head injury was acute subdural hematoma, frequently associated with parenchymal injury, with a large majority interhemispheric in the parieto-occipital region (AIHSH). Follow-up by CT revealed a high incidence of sequelae such as atrophy and infarction. Clinical evidence in this series indicated that AIHSH was due to shaking. A finding of AIHSH is particularly significant because it points to a specific type of injury, clinically manifested by obtusion without physical stigmata of abuse, in which the history is purposefully misleading.

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