Head Trauma Due to Child Abuse: Serial Computerized Tomography in Diagnosis and Management

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ABSTRACT: We studied both the clinical features and CT findings in 24 children who had acute head trauma as a result of child abuse. Twenty-three of them were less than 1 year of age. The diagnosis of whiplash shaken infant syndrome was made in 17. Serial CT, done in 50% of the cases, was useful in managing the medical, legal, and social aspects of the cases and in predicting the neurologic outcome. Three children died and 12 others suffered serious neurologic sequelae. The other five children has lesser degrees of deficit; one was lost to follow-up. Three were neurologically normal on follow-up visits. Two siblings of these children died of child abuse, indicating the necessity for continuing intervention in the abused child's family to prevent further abuse.

TRAUMA to the central nervous system is recognized as the leading cause of morbidity and mortality in abused children.[1] In addition, recent literature suggests that of infants with severe head injury, child abuse may be the major cause.[2] The role of computerized tomography (CT) in rapid diagnosis, documentation, and management of head trauma due to child abuse cannot be underestimated.[3,4] In this article we present a series of young victims of head trauma due to child abuse. We have found serial CT scanning to be of value in managing many of these patients, and we present three cases to illustrate the value of serial CT scans.

METHODS

We reviewed the charts of all children less than 5 years of age admitted to our hospital over a seven-year period (1975 to 1982) with acute head injury. Children were classified as victims of child abuse if any of the following were present: (1) an admission of abuse; (2) multiple injuries unexplained by medical history and evaluation, or by social service evaluation; (3) confirmation of abuse by the Department of Social Services and/or the court system. Six children identified as abused were excluded from the report because they did not have CT scans done. Children were identified as victims of the whiplash shaken infant syndrome (WSIS) first if there was a history of being shaken or thrown into the air, without a history of battering of the head. If no history was available, we followed the guidelines for diagnosis outlined by Caffey,[5] which are "...intracranial and intraocular hemorrhages, in the absence of signs of external trauma to the head or fractures of the calvaria and are associated with traction lesions of the periosteum of the long bones in the absence of fractures and traumatic changes in the overlying skin of the extremities." Our major departure from these essential elements was that we did not require metaphyseal fractures if all the other criteria were met. We acknowledge that it may not be possible to be totally sure a child has not also received a blow to the head in the absence of a reliable history. Children with skull fracture or external head trauma were classified as battered children even though some of them may also have been shaken, as evidenced by retinal hemorrhage in two of seven patients and by intracranial hemorrhage in four of seven. The children were assigned a clinical grade, as described by Zimmerman et al[3] (Table 1), based on initial physical examination. Follow-up was done by chart review and review of repeat CT scans when available (50%). Complete developmental evaluations included assessment by a pediatric neurologist or developmental specialist, age-appropriate psychologic testing, and assessment by a physical therapist and language therapist.

CT scans were done with an EMI 1005 CT scanner using 5 and 10 cm slices at 100 to 120 kVp. Although intravenous contrast medium was injected in 40% of the cases, infused scans rarely added clinically useful information because most of the intracranial hemorrhages were acute and readily identified without contrast.

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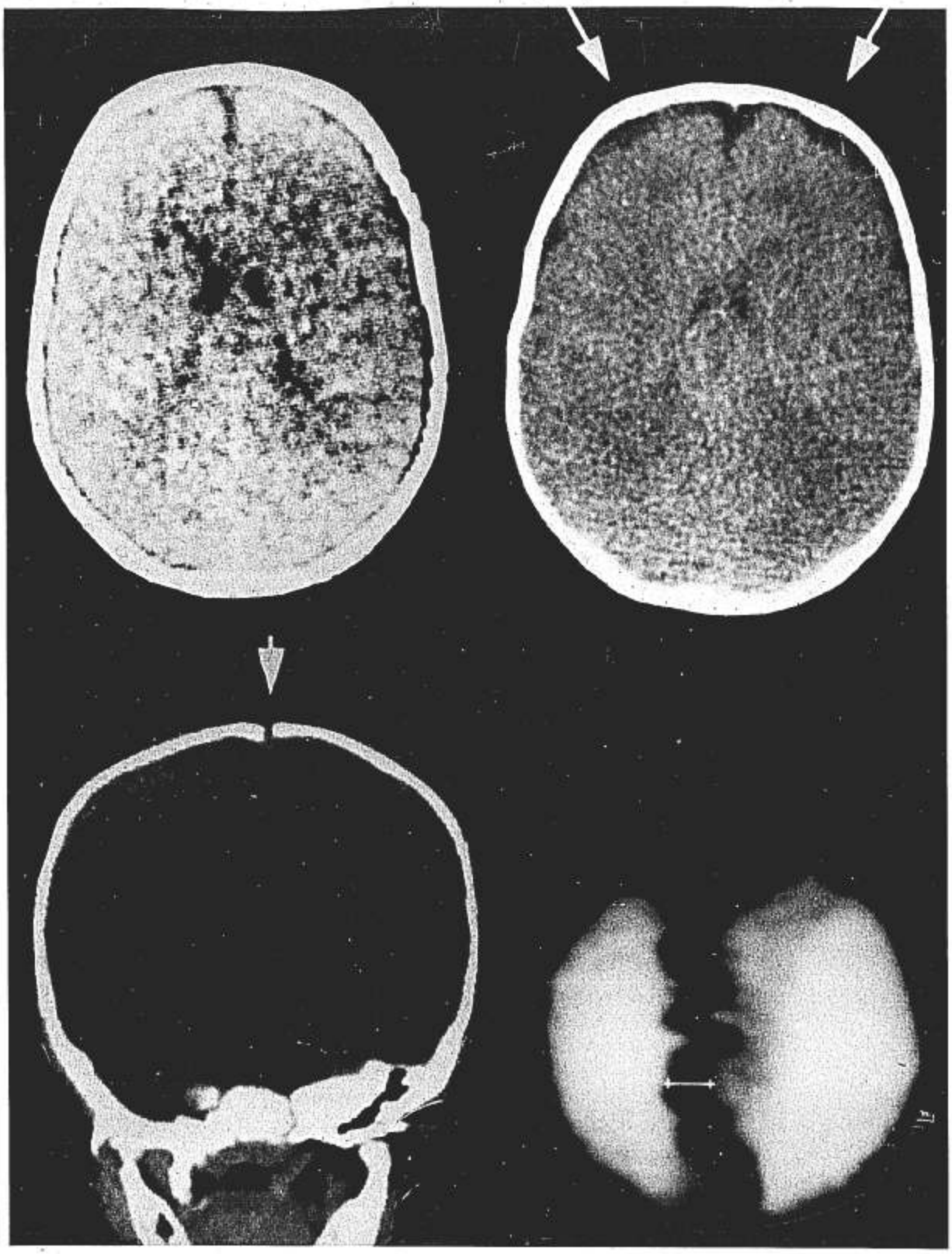

FIGURE 1. (Patient 1) *(Top left)* Normal initial CT scan. *(Top right)* Repeat scan, uninfused, day 5, indicates small lucent extra-axial collections (arrows) in frontal regions. *(Bottom left)* Coronal uninfused scan shows small subdural collection over convexity. Notice lucent subdural collection outlining sagittal sinus in negative relief (arrow), as well as lucent interhemispheric subdural collection. *(Bottom right)* Bone window scan shows split sagittal suture. (Normal <0.2 cm)

TABLE 1. Summary of Clinical and CT Findings

Case	Age (months), Race, Sex	Initial Presentation: Fracture Skull	Fracture Other	Cutaneous	Retinal Hemorrhage	Mechanism of Injury	Clinical Grade*	CT	Follow-up: Neurologic	CT
1	4, W, M	-	Ribs	-	+	WSIS	2	Normal	Mild developmental delay	Day 5: Bilat SD hygroma
2	1, W, F	-	-	Cigarette burns	+	WSIS	3	SAH, intraventricular hemorrhage, ACA lucency	Profound mental retardation, spastic diplegia, blindness, epilepsy	Day 2: SAH, intraventricular hemorrhage, bilat frontal occipital atrophy Day 8: Bilat frontal occipital atrophy Day 23: Severe bilat frontal occipital atrophy
3	3, W, F	-	-	Bruises	+	WSIS	3	SAH	Moderate mental retardation, epilepsy, high myopia	Day 10: SDH Day 24: Chronic SDH, moderate atrophy
4	2, W, M	-	Tibia	Cigarette burns	-	WSIS	1	Bilat subdural hygroma, bilat frontal lucency	Developmental delay, epilepsy, mild CP	Day 300: HC, occipital atrophy
5	7, W, M	-	Radius	Bruises	+	WSIS	4	SAH, unilat lucency, unilat SDH, HC, occipital atrophy	Profound mental retardation, spastic quadriplegia, epilepsy	Day 3: SDH Day 20: HC, severe occipital atrophy
6	2, W, M	-	-	-	+	WSIS	1	Interhemispheric SDH	Normal	
7	1, W, M	-	-	Bruises	+	WSIS	4	No scan	Profound mental retardation, spastic diplegia, epilepsy	Year 4: Unilat atrophy
8	3, B, M	-	-	-	+	WSIS	3	Interhemispheric SDH	Mild developmental delay, attention deficit disorder	
9	5, W, F	-	-	-	-	WSIS	2	Chronic SDH	Profound mental retardation	
10	1, W, M	-	-	Bruise	-	WSIS	4	SAH, intraventricular hemorrhage	Spastic quadriplegia, moderate mental retardation, epilepsy	
11	1, W, F	-	-	-	+	WSIS	4	Bilat occipital lucency	Died	
12	3, W, M	-	-	Bruise	-	WSIS	4	Interhemispheric SDH	Mild mental retardation	Day 2: IH hygroma Day 38: IH hygroma, HC, atrophy Day 67: IH hygroma, atrophy
13	2, W, F	-	-	-	-	WSIS	2	Interhemispheric SD hygroma, SD hygroma, HC	Spastic quadriplegia, profound mental retardation	
14	5, B, F	-	-	-	+	WSIS	4	SAH	Profound mental retardation, spastic quadriplegia, epilepsy, blindness	Day 15: Bilat frontal occipital atrophy Day 32: Severe bilat frontal occipital atrophy
15	9, B, M	-	-	-	+	WSIS	2	Interhemispheric SDH	Mild developmental delay	Day 3: Interhemispheric SDH Day 35: Bilat occipital atrophy
16	7, W, M	-	-	-	+	WSIS	4	Interhemispheric SDH	Mild CP, mild mental retardation	
17	4, B, F	-	-	-	+	WSIS	4	Interhemispheric SDH, SD hygroma	Died	
18	1, B, F	+	-	Bruise	+	Battery	2	SAH	Severe behavior problems, mild CP	Day 7: Bilat SDH Day 27: SDH, HC Day 180: Normal
19	8, W, M	+	-	-	-	Battery	1	No scan	Mild developmental delay	Day 300: Chronic SDH
20	1, W, F	+	-	Bruise	-	Battery	2	SAH	None	
21	1, W, F	+	Femur	Facial bruise	-	Battery	4	SAH, interhemispheric SDH	Hemiparesis, mild developmental delay	Day 94: SD hygroma Year 7: HC, atrophy
22	9, B, M	+	-	Bruises	+	Battery	4	SAH, bilat occipital lucency	Died	
23	10, W, F	-	Multiple long bones	Bruises, hemotympanum	-	Battery	1	Normal	Normal	
24	20, B, M	-	-	Bruises (head)	-	Battery	2	Normal	Normal	

*Clinical grade on admission to hospital. (Modified from Zimmerman et al.[3]) 1 = Minimal or no disturbance of consciousness, 2 = Minimal to moderate disturbance of consciousness, 3 = Significant disturbance of consciousness, 4 = Comatose.

ACA = anterior cerebral artery; CP = cerebral palsy; HC = hydrocephalus; SAH = subarachnoid hemorrhage; SDH = subdural hematoma; WSIS = whiplash shaken infant syndrome.

CASE REPORTS

Patient 1. A 4-month-old white male infant was brought to a local pediatrician's office with a 24-hour history of irritability. He had a generalized tonic-clonic seizure immediately before arrival in the office. There was no history of trauma. The pediatrician transferred him to the medical center with the diagnosis of suspected meningitis. On physical examination, he was very irritable, with a full anterior fontanelle. Eye examination revealed bilateral retinal and vitreous hemorrhages. He was having intermittent generalized seizure activity and was poorly responsive. Spinal fluid was grossly bloody. Results of coagulation studies and the initial CT scan were normal. A skeletal survey revealed four rib fractures. The suspected diagnosis was WSIS. The baby continued to have seizures and to be poorly responsive. Repeat CT with

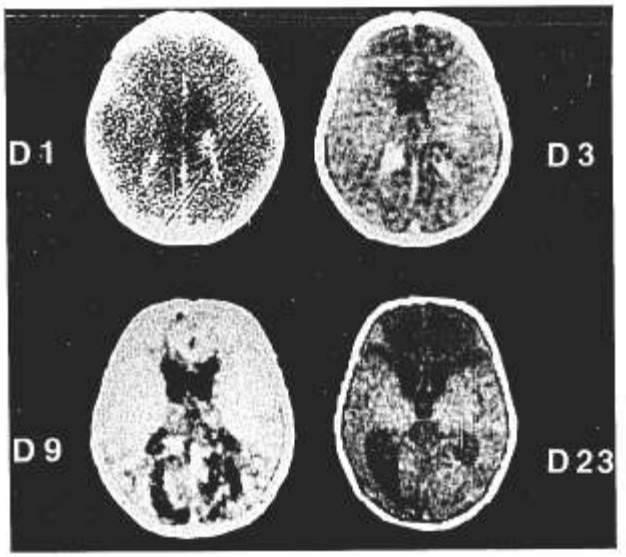

FIGURE 2. (Patient 2) *(Top left)* Initial uninfused scan shows subarachnoid hemorrhage (falx sign), intraventricular hemorrhage, and hydrocephalus. *(Top right)* Scan on day 3 shows medial frontal and bilateral occipital lucencies and intraventricular and subarachnoid hemorrhages. *(Bottom left)* Scan on day 9 shows progression of medial frontal and occipital abnormalities. *(Bottom right)* On day 23, scan shows profound frontal atrophy.

coronal cuts four days later revealed bilateral frontal and interhemispheric subdural hematomas. The baby gradually improved with subdural taps, and was discharged after two weeks to return home with careful supervision by social services and a volunteer trained in parent support services. Follow-up at 1 year of age revealed mild developmental delay. Figure 1 shows the initial and four-day follow-up CT scans. A high index of suspicion in the face of retinal hemorrhages justifies a follow-up scan and/or subdural taps. This was our only case of WSIS in which the initial scan was normal, though the two oldest abused children, ages 10 and 20 months, had normal initial scans.

Patient 2. A 5-week-old white female infant was brought to the pediatric emergency room at our medical center with a three-day history of poor feeding and vomiting. On the day before arrival she was lethargic, refused feedings, and developed a left-sided tonic-clonic seizure. The parents denied trauma to the baby. The father had recently started babysitting while the mother worked because he had been fired from his job. Physical examination showed left-sided seizure activity and unresponsiveness, as well as a lesion that appeared to be a cigarette burn on the right fifth finger. Eye examination revealed bilateral vitreous and retinal hemorrhages. Spinal fluid was grossly bloody. Skeletal survey was negative. CT on admission revealed intraventricular hemorrhage (IVH), subdural hematoma (SDH), and subarachnoid hemorrhage (SAH). Because of poor clinical progress and continued signs of increased intracranial pressure, the scan was repeated in 24 hours; it showed SDH, SAH, IVH, and bilateral frontal and occipital lucencies. Multiple subdural taps were done over the next two weeks. Two subsequent scans at one week and one month after admission showed mild hydrocephalus and developing encephalomalacia in the anterior cerebral artery territories, and bilateral frontal and occipital atrophy (Fig 2). The child was discharged to a foster home after six weeks. On follow-up four years later, she exhibits severe mental retardation, spastic diplegia, and blindness. She has remained in foster care at the mother's request. The father committed suicide one year after the child's injury.

TABLE 2. Suggested Indications for Follow-up CT Scans in Children With Head Trauma Caused by Abuse

1. To prove the diagnosis of subarachnoid hemorrhage by resorption in subtle cases.
2. To distinguish layered acute subdural hematoma (SDH) from chronic SDH.
3. To monitor developing or changing lesions in patients with progressive deficits.
4. To rule out isodense SDH.
5. To rule out communicating hydrocephalus.
6. To confirm the diagnosis in patients with normal initial scan but with retinal hemorrhages or neurologic deficit.
7. To demonstrate frontal/occipital atrophy confirming whiplash shaken infant syndrome.
8. To suggest prognosis by the extent of organic damage at 3 to 6 weeks.

Patient 3. A 3-month-old white female infant was brought to a local pediatrician's office with a history of vomiting for several days. On the day of the visit, the child had a choking episode 30 minutes after feeding and turned blue. In the pediatrician's office, the child was intermittently apneic, and was transported to our medical center, requiring stimulation en route. The parents denied trauma, but the mother stated that her husband was often "too rough" with the baby and would throw her up in the air. The father had been alone with the child for two hours before the choking episode. Social history revealed that the mother was a battered wife and had had her first child while living at the battered women's shelter one year earlier. She had returned home to live with her husband when her first child was 1 month old; that child died suddenly two weeks later with retinal hemorrhages and SAH.

On physical examination, the infant was lethargic, with shallow respirations. Petechiae were noted over both thighs. Bilateral retinal hemorrhages were present, and the spinal fluid was grossly bloody. Skeletal survey was negative. A CT on admission revealed a small SAH. Repeat CT ten days later showed a left subdural hematoma with a midline shift. The child had multiple subdural taps and was discharged after five weeks. Repeat CT one month later showed chronic SDH and atrophic changes (Fig 3). She currently lives in an adoptive home and is believed to be moderately retarded at 2 years of age.

RESULTS

Clinical and CT findings on these patients are summarized in Table 1. Of the 24 children found to have acute head injury due to abuse, 13 were male and 11 female; 17 were white and seven black. They ranged in age from 1 to 20 months, but 23 of the 24 were less than 1 year old. The diagnosis of WSIS was made in 17; only three of these patients were over 6 months of age, and none was older than 9 months. Skull fractures were found in five children who were classified as battered. Additional physical findings supporting evidence of trauma were long bone fractures (five cases), rib fractures (two cases), burns (two cases), and significant bruising (four cases). In 12 of the 17 cases of WSIS (71%) there were retinal hemorrhages; only two of the seven battered children (29%) had retinal hemorrhages.

CT scans were done in all cases; 23 of the 24

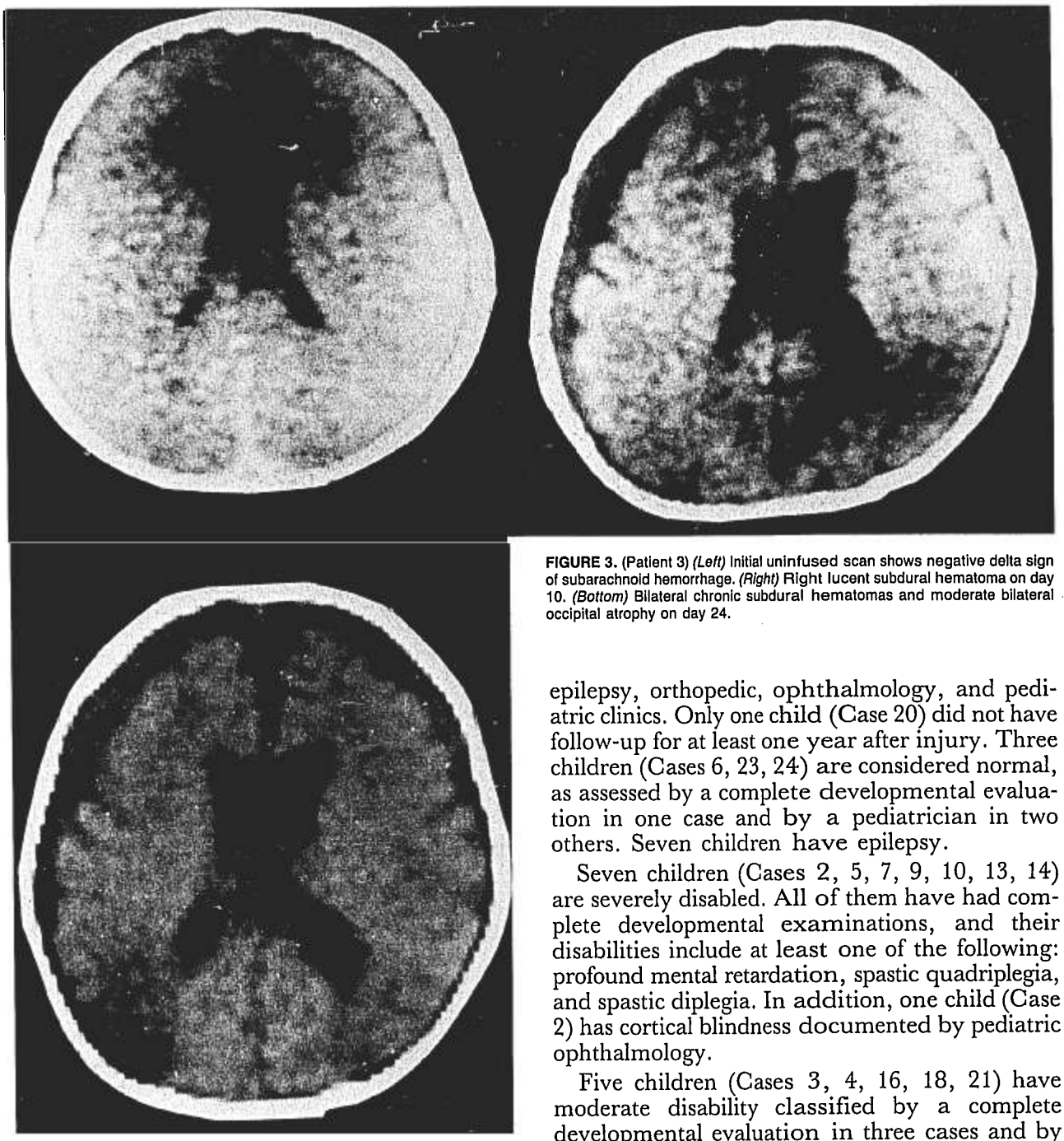

FIGURE 3. (Patient 3) *(Left)* Initial uninfused scan shows negative delta sign of subarachnoid hemorrhage. *(Right)* Right lucent subdural hematoma on day 10. *(Bottom)* Bilateral chronic subdural hematomas and moderate bilateral occipital atrophy on day 24.

patients had scans at diagnosis, 12 had serial scans, and eight had multiple follow-up scans, including a scan 20 days or more after admission.

Follow-up examinations by chart review were done on all children. Findings are detailed in Table 1. Three children (Cases 11, 17, 22) died as a result of their injuries. Because of severe handicaps as a result of the head trauma, many of the children are seen regularly at our medical center's developmental, neurosurgery, neurology, epilepsy, orthopedic, ophthalmology, and pediatric clinics. Only one child (Case 20) did not have follow-up for at least one year after injury. Three children (Cases 6, 23, 24) are considered normal, as assessed by a complete developmental evaluation in one case and by a pediatrician in two others. Seven children have epilepsy.

Seven children (Cases 2, 5, 7, 9, 10, 13, 14) are severely disabled. All of them have had complete developmental examinations, and their disabilities include at least one of the following: profound mental retardation, spastic quadriplegia, and spastic diplegia. In addition, one child (Case 2) has cortical blindness documented by pediatric ophthalmology.

Five children (Cases 3, 4, 16, 18, 21) have moderate disability classified by a complete developmental evaluation in three cases and by a neurosurgeon in two. The disabilities include at least one of the following: moderate mental retardation, mild cerebral palsy, and severe behavior disorders.

Five children (Cases 1, 8, 12, 15, 19) have mild disability, classified by complete developmental assessment in two cases and by a pediatrician in three cases.

Our case review also revealed that siblings of two of the patients also died of child abuse. In one instance the 6-week-old sibling died before the birth of our patient and was not confirmed as a

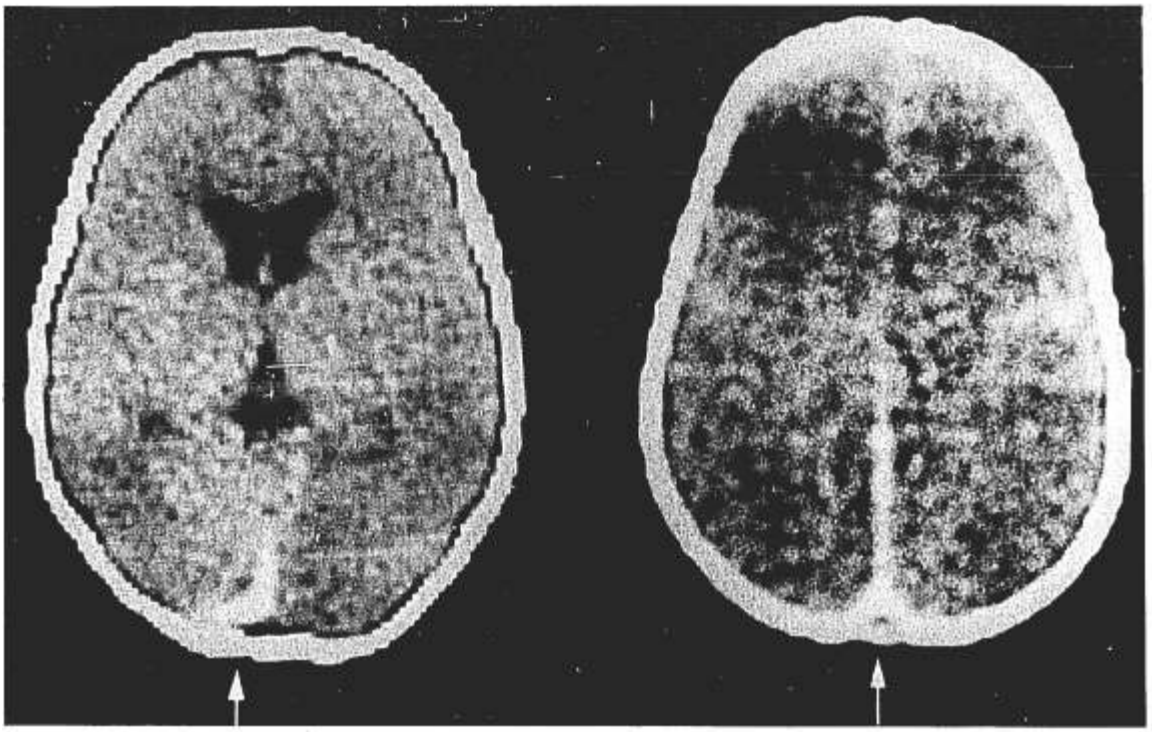

FIGURE 4. *(Left)* Uninfused scan shows posterior interhemispheric subdural hematoma (arrow) extending asymmetrically along falx. *(Right)* Uninfused scan shows symmetric blood density along falx, negative delta sign of subarachnoid hemorrhage.

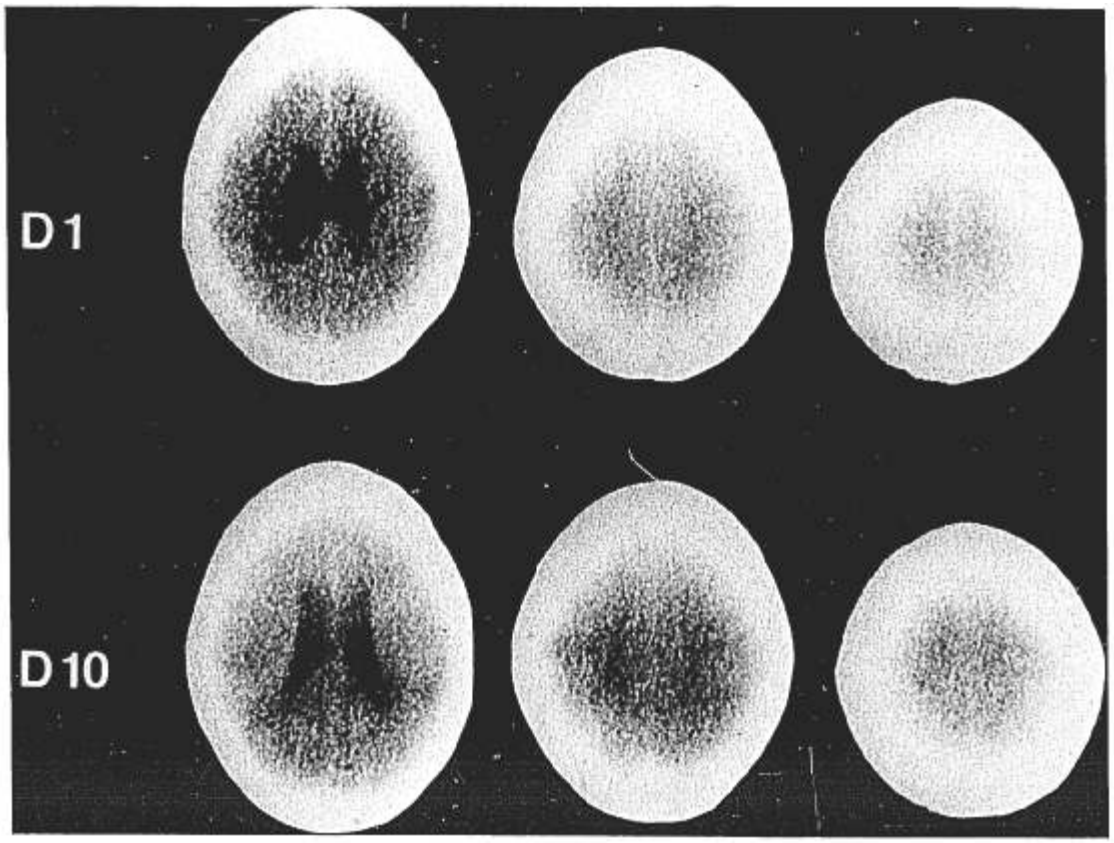

FIGURE 5. Uninfused CT scans day 1 (D1) and day 10 (D10). Interhemispheric stripe of increased density disappears in higher images on repeat scan at ten days, confirming subarachnoid hemorrhage on initial scan.

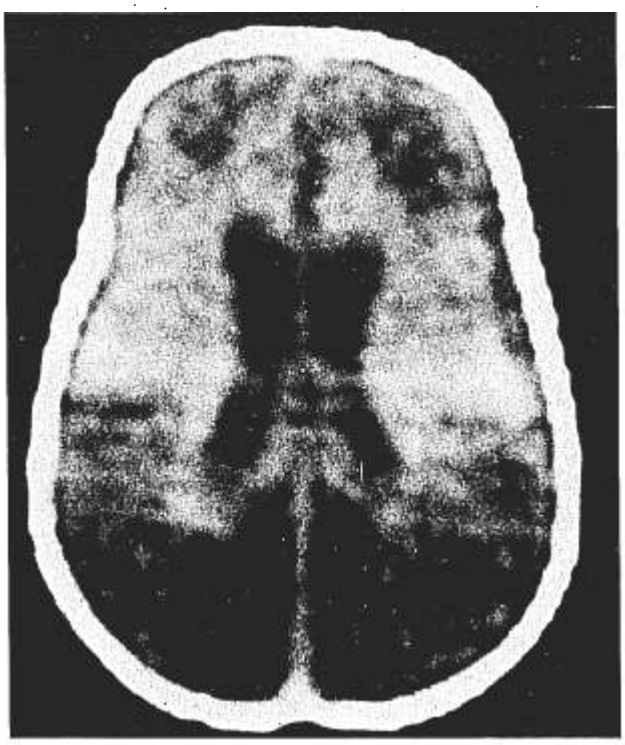

FIGURE 6. (Patient 14) Profound frontal-occipital atrophy on follow-up scan (day 32) of whiplash shaken infant.

FIGURE 7. (Patient 6) Retinal hemorrhage in right globe of whiplash shaken infant's initial scan.

battered child. Chart review did, however, reveal retinal hemorrhages and SAH in this child, and abuse had been considered. In the second case, the sibling was born while our patient was in foster care; the social workers were unaware of the birth of a sibling. The sibling death was alleged to be a crib death until autopsy revealed a fractured spine and subdural hematomas.

DISCUSSION

Child abuse may produce head trauma when the child is struck in the head by fists or other blunt objects. The child may be used as a club or thrown into a hard object. Whiplash caused by shaking was the most common form of head injury in young infants in our series, comprising 71%. In this syndrome, first recognized by Caffey,[5,6] the younger infant is highly vulnerable to injury because the head is large and poorly supported by weak neck musculature. The pathophysiology has been well described; with vigorous shaking, the child's head undergoes repeated sudden acceleration and deceleration, causing shearing of brain parenchyma and rupture of bridging veins between the cortex and the venous sinuses.[7,8]

Caffey[6] recognized the association of long bone fracture and subdural hematoma in the 1946 article establishing the battered child syndrome. CT exquisitely demonstrates the intracranial hemorrhages associated with child abuse.[3,9] Our series confirms that CT detects small amounts of intracranial hemorrhage, allowing the diagnosis of small subdural hematomas and subtle subarachnoid hemorrhages. Figure 4 shows the thin subdural blood collection layered posteriorly adjacent to one side of the falx cerebri and the sagittal sinus. This differentiates interhemispheric SDH from SAH, which layers posteriorly on both sides of the falx and both sides of the sagittal sinus, comprising an empty triangle sign on the uninfused CT scan. Ten of our 17 infants with WSIS had subdural collections on the initial scans. Coronal scanning may be helpful in demonstrating small subdural collections (Fig 1). Zimmerman et al[3] recognized the frequent association of the subtle interhemispheric subdural hematoma, which was present on initial scans in seven of 17 cases of WSIS. However, subarachnoid hemorrhage (SAH), which has been underemphasized, was found on the initial CT in nine of 23 patients, including seven without subdural hematoma. In questionable cases of SAH, follow-up scanning within five to ten days will show resorption of the subtle SAH (Fig 5).

In the management of child abuse cases, obtaining the most accurate medical assessment of the injury becomes important, not only for appropriate medical management, but for management of the social situation as well. Social workers, attorneys, and judges involved in making a disposition for a child abuse victim will look to medical authorities to outline the child's injuries, to time the occurrence of the injury, to suggest the mechanism of injury if possible, and to

speculate as to the child's prognosis. CT scans, particularly serial scans, in combination with clinical findings, are of great value in accurate diagnosis of the type and extent of the head trauma and in suggesting the mechanism of injury. Bilateral frontal and occipital atrophy are highly suggestive of the coup/contrecoup trauma of shaking-induced whiplash.

Serial CT may be helpful in predicting outcome. Six infants received follow-up scans between 20 and 35 days after admission. The three patients with severe atrophy (Cases 2, 5, 14) had the worst outcomes (Figs 2 and 6), Patient 3 had moderate atrophy and moderate disability (Fig 3), and Patients 12 and 15 (with less atrophy) had mild disability. Patients 4, 7, and 21 showed atrophy on long-term follow-up at 1, 4, and 7 years, and were moderately to severely retarded. No patient who had atrophy on follow-up CT examination after 20 days had a normal outcome.

Three patients' initial CT scans were normal. In Cases 23 and 24, scans were still normal at long-term follow-up, but repeat scans in Case 1 showed bilateral subdural hematomas at day 5 and mild developmental delay on long-term follow-up. The other patient with a normal outcome (Case 6) had only interhemispheric subdural hematoma and retinal hemorrhage on initial CT scan (Fig 7).

Although there are cheaper methods of diagnosing subarachnoid hemorrhage (eg, lumbar puncture), it has been our experience that the possibility of a traumatic tap, particularly with serial taps, can make this evidence confusing. It is also true that serial neurologic examinations will eventually reveal a child's neurologic potential, but the law in North Carolina and most other states dictates that these cases be brought to court promptly. Whether the child can safely return home after hospitalization is a major issue to be dealt with, and many of these cases will be prosecuted in criminal court. We have found the serial CT scans to be of immense value in allowing us to give accurate, reliable testimony in a timely fashion when the stakes are high.

A high index of suspicion for the possibility of child abuse in cases of intracranial injury is necessary. CT scans should be performed on infants with altered consciousness in the presence of suspected trauma, retinal hemorrhages, long bone or rib fractures, burns, or excessive bruising. Skeletal survey should be obtained in these suspect cases. The CT demonstration of acute dense SAH or SDH in the full-term infant 3 weeks old or older is highly suggestive of WSIS; SAH is absorbed in less than ten days and subdural hematomas become lucent collections within three weeks, ruling out birth trauma as the cause of acute intracranial hemorrhage at this age. In determining timing of the injury, one must also consider the possibility of a layered subdural hematoma, which implies an injury one to seven days old, versus a chronic lucent subdural hematoma, implying an injury more than two or three weeks old. However, underlying parenchymal injury rather than extra-axial hematoma is most significant in outcome because the calvarium can easily enlarge to accommodate extra-axial hemorrhage at this age. In severe cases of WSIS with long-term survival, frontal/occipital brain injury characteristically appears; marked polar atrophy is often accompanied by severe disability.

Serial CT scans may confirm the diagnosis, suggest time of injury, discover complications, and suggest prognosis. Table 2 lists suggested indications for follow-up scanning.

Accurate diagnosis is the first step in preventing further injuries of these children. Continuing intervention in the abused child's family is also necessary, as illustrated by the fatal abuse of siblings of two of our 17 patients with whiplash shaken infant syndrome.

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