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Post-traumatic diffuse brain swelling: isolated or associated with cerebral axonal injury

Clinical course and intracranial pressure in 18 children

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Abstract. Eighteen children with severe head injuries and diffuse brain swelling were studied. They were separated into two groups based on the computed tomography (CT) findings. Seven patients had small ventricles in the normal location and small or absent cisterns. Eleven had these signs plus small deep-seated intraparenchymal hemorrhagic foci and/or intraventricular hemorrhage. Patients in the first group were in relatively good neurological condition; their intracranial pressure was easily controlled and all had a favourable outcome. On contrast, children in the second group had a more severe clinical presentation, frequently had uncontrollable intracranial hypertension, and more than 50% died.

Key words: Head injury – Children – Computed tomography – Diffuse brain swelling – Intracranial pressure – Glasgow Coma Scale.

Post-traumatic diffuse brain damage has been better defined since the advent of computed tomography (CT) [3, 4–6, 11, 22, 23]. Diffuse brain swelling (DBS), manifested by absent or slit-ventricles and cisterns, which is the most frequent finding in children with acute head injury, appears to be caused by an increase in intracerebral blood volume and has a good prognosis [2, 3, 5, 22].

Post-traumatic diffuse axonal injury (DAI), diffuse shearing injury of the cerebral white matter, and diffuse brain damage of the primary impact type are different names for the same brain lesion; all have a very poor prognosis [1, 6, 12, 23]. DAI was firstly predicted by Holbourn [8], described in postmorten material by Strich [21], and studied in its pathological course by Adams et al. [1]. The CT findings of DAI were described by Zimmerman et al. [23]. These authors found small eccentric hemorrhages in the corpus callosum, the internal capsule, the periventricular gray matter, and the posterolateral upper part of the brain stem; DBS was also frequently associated.

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An occasionally unexpected bad prognosis in patients with DBS is most likely due to associated DAI that cannot be demonstrated by the CT scan. In this report we compare the clinical and intracranial pressure (ICP) findings in 18 children with severe head injuries and either isolated DBS or DBS associated with DAI.

Patients and methods

This series included 18 unselected children who were studied between January 1981 and March 1984; they had presented CT signs of DBS after sustaining a severe closed head injury. These patients represented nearly 30% of the severe head injury series seen during the same period in the Pediatric Neurosurgical Unit of our hospital. Patients were considered to have a severe head injury when they were unable to open their eyes despite painful stimuli, to speak, to obey commands for at least 6 h after the injury, or subsequent deterioration (1 case). There were 12 males and 6 females, who ranged in age from 4 to 14 years (average 9.3 years). Injury was sustained in a traffic accident in 17 cases and after blunt trauma in 1.

CT studies consisted of four-slice unenhanced scans performed with an EMI brain scanner (160×160 matrix). All 18 patients were scanned immediately after admission and within 6 h of injury, and 15 patients had sequential CT scanning within the next 72 h.

The CT imaging criteria for defining DBS were small undisplaced ventricles with absent or collapsed cisterns; some patients had intraventricular and/or petechial hemorrhages superimposed on the above-mentioned findings. Intraparenchymal hemorrhages were never greater than 20 mm in diameter. Intraventricular hemorrhage was diagnosed as primary when it was present in the admission scan before intraventricular pressure monitoring was undertaken.

Continuous measurement of the ICP was started within 24 h of admission in all patients by means of an intraventricular catheter (13 cases) or an epidural fiber-optic sensor (5 cases). ICP measurement was considered reliable when the CSF pressure pulse and variations in the pressure level induced by changes in the cephalic venous pressure were clearly reflected in the recording chart. The average duration of ICP recording was 4.1 days. Patients were managed with relaxant therapy and artificial ventilation to maintain the arterial pCO_2 between 25 and 30 mm Hg and the pO_2 over 75 mm Hg. Dexamethasone 1 mg/kg day was administered in all cases. Intracranial hypertension was firstly treated with mannitol and diuretics. Barbiturates were used in 8 patients who had raised ICP uncontrollable by the above mentioned measures.

Clinical evaluation of patients in the intensive care unit was made by using the Glasgow Coma Scale (GCS), and the final outcome was graded at least 1 year after the injury according to the Outcome Scale of Jennett and Bond.

Results

Patients were classified into two groups. *Group A* includes 7 patients with DBS as the unique finding. Three patients had absent cisterns and four collapsed but still visible cisterns. The average age in this group was 9 years. Only two patients had anisocoria at admission. The average GCS score during the first 24 h was 5.1. The duration of coma was less than 48 h in 3 patients and less than 10 days in the remaining patients (Table 1). ICP was always within normal limits in 5 patients, the other 2 having moderately controllable intracranial hypertension at some time during the course (Fig. 1). Six patients in this group made a complete recovery and one became moderately ataxic. This last patient always had normal ICP and showed unequivocal signs of supra and infratentorial atrophy in the control CT scan performed 1 year after trauma (Fig. 2). Late CT controls in the other 6 patients showed widened sulci and cisterns (2 cases) or a normal result (4 cases).

Group B includes 11 patients with CT signs of DBS plus small intraparenchymal hemorrhages (6 cases), intraventricular hemorrhage (1 case), or both (4 cases). Intraparenchymal hemorrhages varied from 1 to 3 in number in most cases located in the deep white matter of the cerebral hemispheres. Four patients had brain-stem hemorrhagic contusion (Fig. 3). Intraventricular hemorrhage occupied the lateral ventricles in 3 patients, the IV ventricle in 1 and the whole ventricular system in another patient. The ambient cistern was absent in 6 patients and showed partial collapse in 5. The average age in this group was 9.6 years and the average GCS score at admission 4.2 (Table 1). Five patients had abnormal pupils when admitted and

Table 1. Final outcome, clinical findings at admission, and duration of coma in the survivors; 18 children had sustained severe head injuries and diffuse brain swelling with (group B) or without (group A) associated axonal injury

	Group A (*N*)	Group B (*N*)	Total
Outcome			
Good recovery	6	2	8
Moderate disability	1	–	1
Severe disability	–	2	2
Vegetative	–	1	1
Death	–	6	6
Total	7	11	18
Pupillary status at admission			
Normal	5	6	11
Anisocoria	2	3	5
Bilateral mydriasis	–	2	2
Glasgow Coma Scale score at admission			
3	–	2	2
4	4	7	11
5	–	1	1
6	2	–	2
7	1	1	2
Duration of coma in survivors			
Less than 48 h	3	–	3
2 to 7 days	2	1	3
7 to 14 days	2	1	3
More than 14 days	–	3	3

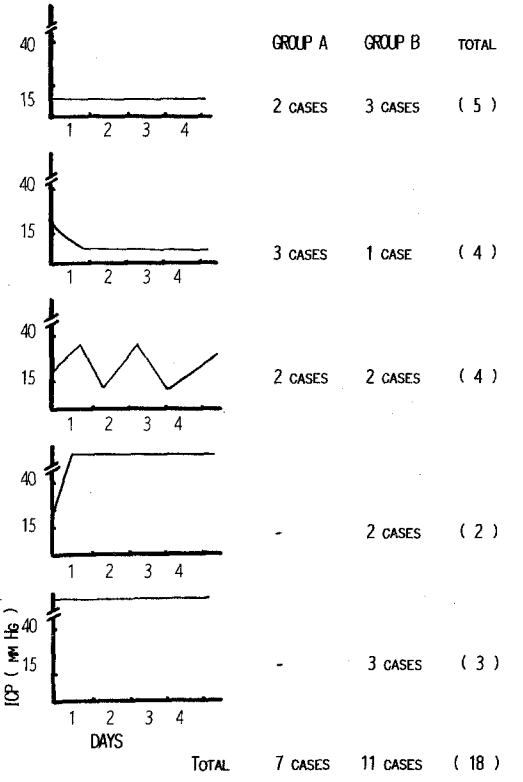

Fig. 1. ICP profiles of 18 children with severe head injuries who showed diffuse brain swelling with (*group B*) or without (*group A*) associated axonal injury

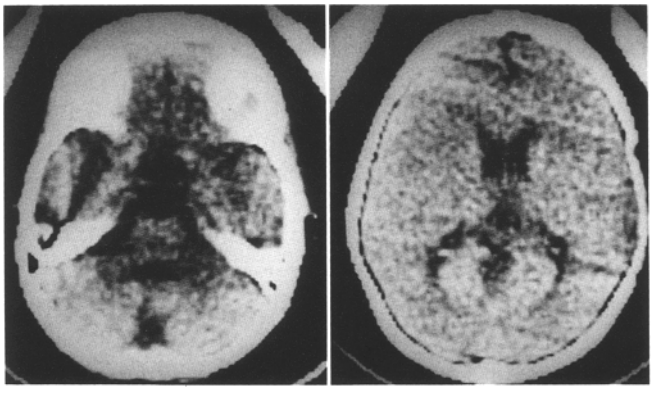

Fig. 2. Supra- and infratentorial brain atrophy is appreciated in the late CT control (1 year after trauma) in an 8-year-old girl who had been in a traffic accident. Admission CT scan had showed diffuse brain swelling and ICP was within normal limits

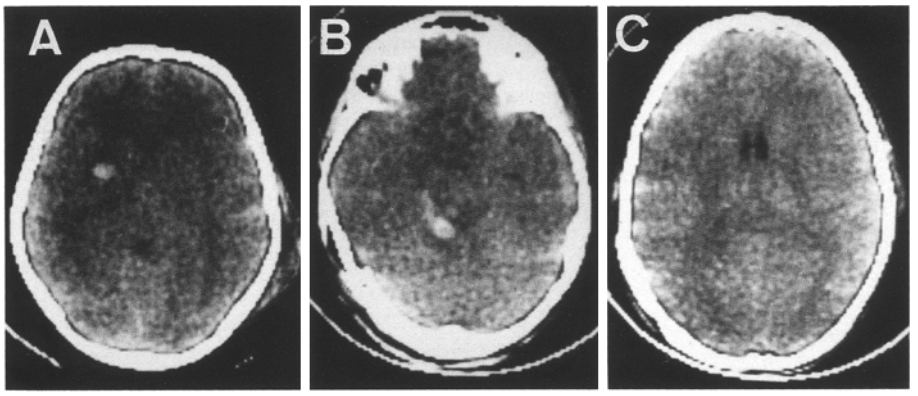

Fig. 3. **A** Admission CT scan of a patient who made a good recovery after suffering an acute head injury. An intraparenchymal clot at the left basal ganglia is present. **B, C** Correspond to an admission CT scan of a patient who entered the hospital with bilateral mydriasis and died after 3 days

Table 2. Mean intracranial pressure (IC) related to the final outcome in 18 children with severe head injuries who showed diffuse brain swelling with (group B) or without (group A) associated axonal injury. GR, Good recovery; MD, moderate disability; SD, severe disability; V, persistent vegetative status; D, death

ICP (mm Hg)	Group A						Group B					
	GR	MD	SD	V	D	Total	GR	MD	SD	V	D	Total
< 15	4	1	–	–	–	5	1	–	1	1	1	4
15–40	2	–	–	–	–	2	1	–	1	–	1	3
> 40	–	–	–	–	–	–	–	–	–	–	4	4
Total	6	1				7	2	–	2	1	6	11

only two patients had a good outcome. Six patients died within the first 4 days of trauma, 2 developed a severe disability, and the other remained in a vegetative state 1 year after the injury. Three out of the 5 survivors in this group showed posturing and remained in a deep coma for periods longer than 2 weeks. ICP was found to be increased immediately after admission in 8 of the 11 patients and 5 developed uncontrollable intracranial hypertension (Table 2). Of the 4 patients showing brain-stem contusion, 3 died and the other went into a vegetative condition; 2 of these last patients had normal ICP through the course and the other 2 developed uncontrollable intracranial hypertension. Late CT controls in this group showed widened CSF spaces in all survivors except 1 who made a good recovery.

Discussion

Although it is sometimes difficult to distinguish normal from reduced CSF spaces on the CT scan studies [11, 20], DBS is defined as the compression or absence of the lateral and III ventricles and the perimesencephalic cisterns [3, 20, 22]. DBS, a post-traumatic lesion that has been demonstrated in experimental works [15, 17] is a very frequent post-traumatic lesion in children suffering acceleration/deceleration cranial injuries and seems to be caused by an increase in cerebral blood volume [3]. Electron microscopic studies have corroborated this lesion [18]. The proportion of cases classified as suffering DBS in severe head injury series ranges from 5% to 41% [2–5, 9, 12], but this lesion may also be seen in patients with minimal or no disturbance of consciousness [20, 22].

DAI is a different lesion that can be reproduced in subhuman primates by using nonimpact, controlled angular acceleration of the head [7]. Its CT presentation may range from a normal scan [19] to the picture first described by Zimmerman et al. [23]. Patients with this type of lesion are usually in deep coma from the outset and have an unfavorable outcome [1, 3–5, 12, 19]. DBS has been described in association with DAI in the various reports [4, 19, 23].

In the present series children with isolated DBS clearly showed a better clinical course than those with associated DAI. Although being unconscious from the outset, children with DBS awakened earlier and had a very good outcome. The only disabled patient showed signs of atrophy on the late control CT scan, a finding suggesting the occurrence of associated diffuse impact injury. Patients with DBS associated with DAI presented with deep and prolonged coma, and only 8% made a good outcome while more than 50% died. A brain-stem lesion could be demonstrated by the CT scan in 36% of these patients.

The great value of recording the intracranial pressure in neurosurgical practice, especially in cases of severe injury of the brain without hematoma, has been emphasized by Lundberg and his associates [13, 14]. ICP findings in patients suffering post-traumatic DBS are controversial. In patients with diffuse brain injury Murphy et al. observed that the complete obliteration of the III ventricle

and the ambient cistern was a reliable sign of intracranial hypertension, while the partial collapse of these two structures was rarely associated with high ICP [16]. Bruce et al. found mild, controllable intracranial hypertension in 17 of 29 patients with DBS during the first 3 days after trauma, and none of these patients died [3]. Other authors have described cases with uncontrollable intracranial hypertension, mainly when post-traumatic DBS coexisted with DAI [4, 10, 12]. In the present series, ICP was found to be increased at some period in the course in 72% of the cases; in 28% of those patients who had associated DABI, there was severe intracranial hypertension.

We conclude that patients with post-traumatic DBS as the only finding usually have a benign clinical course and show either normal ICP or moderate intracranial hypertension within the first days of injury. When DBS is associated, DAI patients usually are in a poor neurological condition, with intracranial hypertension and an unfavorable outcome.

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