Diffuse brain swelling after head injury: more often malignant in adults than children?


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A series of 118 patients with diffuse traumatic brain swelling was studied retrospectively in order to compare the clinical findings in children with those in adults, and to determine the occurrence of neurological deterioration and outcome. The computerized tomography (CT) picture of absent third ventricle and basal cisterns was used to identify the cases. Although this condition has been associated with children, we found the same number of children and adults (59 cases each). Secondary deterioration (decline in consciousness, the development of new focal neurological signs, or an increase in intracranial pressure) occurred in 40% of cases and was more common in adults than children. Features that were significantly associated with deterioration were the presence of prolonged coma (> 1 hour) after the injury, CT signs of diffuse axonal injury or subarachnoid hemorrhage, or a recorded episode of hypotension. A moderate or good recovery at 6 months was achieved by 70 patients (59%), but 45 patients had a poor outcome (severe disability in nine, vegetative state in three, and death in 33) and this was often a consequence of secondary deterioration. In three patients, the outcome was not known. The combination of a severe initial injury, secondary insult, and diffuse swelling is associated with a poor outlook, particularly in adults. The CT appearance of diffuse swelling may develop more readily in children because of the lack of cerebrospinal fluid available for displacement. In children, diffuse swelling may have a relatively benign course unless there is a severe primary injury or a secondary hypotensive insult.

**KEY WORDS** • head injury • brain swelling • outcome • children

**COMPUTERIZED tomography (CT) has made it possible to recognize diffuse brain swelling in head-injured patients.** In spite of several studies on this clinical sign, there is still uncertainty about its consequences and causes, particularly about the risk that it will lead to neurological deterioration and a poor outcome. Some patients with CT findings of diffuse brain swelling deteriorate and die whereas others have a good outcome. Most of these previous studies were restricted to certain categories of patients, such as children or patients in coma; others focused on how head-injured patients with diffuse brain swelling differed from those with other types of diffuse brain damage. These studies provided little information on features that might identify different subgroups of patients with diffuse brain swelling. We have therefore reviewed a large series of patients with CT signs of diffuse swelling. Our aims were to compare the findings in children with those in adults, to determine the incidence and outcome of neurological deterioration, and to seek features that might identify patients at high risk of deterioration and a poor outcome.

**Clinical Material and Methods**

The patients had first been admitted to a general hospital and then transferred for assessment to the regional neurosurgical unit at the Institute of Neurological Sciences in Glasgow, which provides neurosurgical services for 2.7 million people in the west of Scotland. Patients with a head injury are received and resuscitated in a general hospital, then transferred for CT scanning and neurosurgical assessment according to accepted guidelines.

We studied 118 consecutive patients diagnosed by the neuroradiologist as having diffuse brain swelling. All of these patients had been part of a large prospective neuroradiological study carried out between 1978 and 1982. Forty-nine patients with diffuse brain swelling were identified from the 1-year consecutive series of 528 patients reported in 1990 by Macpherson,
et al.,17 and the other 69 cases were identified from the neuroradiological database. The inclusion criteria for the study were rigorously applied. Diffuse brain swelling was diagnosed by the neuroradiologist when either the third ventricle or basal cisterns were absent in patients without a significant (operable or occult) intracranial mass lesion and with a midline shift of less than 6 mm. The neuroradiologist also reported on the presence of hemorrhage, infarction, contusion, and features that are associated with shearing forces in the white matter: "gliding contusions" and lesions in the corpus callosum and dorsal midbrain.19

The case records were reviewed, and each patient's clinical course was determined from serial assessments of consciousness level using the Glasgow Coma Scale (GCS).23 Coma was defined as the inability to open eyes, obey commands, and speak. This usually implied a summed GCS score of 8 or less. The presence of a lucid interval between injury and CT scanning was determined where possible, and the occurrence of seizures was noted. Particular attention was directed to recording episodes of hypotension and hypoxia. Hypotension was defined as a sustained fall in systolic blood pressure to 100 mm Hg in adults and 80 mm Hg in children. Hypoxia was defined in both groups as a PaO₂ of less than 60 mm Hg. Major extracranial injuries that alone would have led to admission to hospital were noted. In selected patients, usually those who were intubated, paralyzed, and ventilated, intracranial pressure (ICP) monitoring was carried out.

Deterioration was determined from a change in consciousness level as assessed by the GCS, the development of new focal neurological signs, or a sustained elevation of ICP (> 30 mm Hg for longer than 20 minutes). Outcome was assessed at 6 months using the Glasgow Outcome Scale (GOS).13

Results

Patients Studied

There were 59 adults and 59 children (< 14 years old). Their ages ranged from 3 weeks to 59 years; the median age was 8 years in the pediatric group and 23 years in the adult group. Most of the adults (48) were male while 34 of the children were male and 25 were female. Fifty patients (42%) underwent CT within 3 hours of injury, and 89 (75%) within 6 hours of injury; only 10 (8%) had their first CT scan after 24 hours postinjury.

Clinical Features

Eighty-seven patients (74%) were injured due to a road-traffic accident. Only eight patients did not lose consciousness at the time of injury, 22 patients were drowsy or confused (GCS score 9 to 13), 36 were in coma for more than 6 hours, and 52 were in coma for less than 6 hours. Overall, 92 patients were in coma for 1 hour or more and 18 for less than 1 hour. Table 1 shows the cause of the injury, its effect on level of consciousness, and the presence of other clinical features before CT was carried out. Intracranial pressure was monitored in 31 patients; 16 patients had elevated ICP immediately after insertion of the monitor, nine patients rapidly developed increased ICP, and only six did not have intracranial hypertension.

Radiological Features

Radiographic studies revealed a linear fracture in 65 patients and a depressed skull fracture in 14; 36 patients had no skull fracture. In three patients, we could not determine whether or not there was a fracture.

On CT scans, 100 patients had no midline shift and 18 had shift of less than 6 mm. In 54 patients there was subarachnoid or intraventricular blood. The CT findings are summarized in Table 2. Contusions and hematomas were not considered to be surgically significant and did not exert mass effect. The appearance of the cerebrospinal fluid (CSF) spaces is shown in Table 3. The third ventricle was obliterated in 107 patients and the basal cisterns were absent in 57. In five patients the first scan was inconclusive but an early repeat scan showed obliteration of the third ventricle or basal cisterns.

Management

All patients had careful monitoring of fluid balance, blood pressure, and blood gas levels. Five patients received steroids, in four cases these were given before transfer to the neurosurgical unit; 20 received mannitol. Forty-eight patients were ventilated. Fourteen patients underwent surgery: four required urgent general surgical, orthopedic, or maxillofacial procedures; three had a depressed fracture elevated; one developed a delayed extradural hematoma which was evacuated; and...
Diffuse brain swelling after head injury

**TABLE 2**
Classification of CT findings in 118 patients with diffuse brain swelling*

<table>
<thead>
<tr>
<th>Feature</th>
<th>Adults</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of cases</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>swelling only</td>
<td>18</td>
<td>35</td>
</tr>
<tr>
<td>swelling + subdural hematoma</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>swelling + extradural hematoma</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>swelling + diffuse shearing lesions</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>swelling + contusions</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>swelling + SAH</td>
<td>29</td>
<td>17</td>
</tr>
</tbody>
</table>

* Some patients exhibited more than one feature. CT = computerized tomography; SAH = subarachnoid hemorrhage.

**TABLE 4**
Type and timing of neurological deterioration in patients with diffuse brain swelling

<table>
<thead>
<tr>
<th>Mode &amp; Timing of Deterioration</th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>no of cases</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>no deterioration</td>
<td>42</td>
<td>35</td>
</tr>
<tr>
<td>deterioration in consciousness</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>development of focal signs</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>increase in ICP alone*</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>deterioration in &gt;1 feature</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>time from injury to deterioration</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>&lt; 24 hrs</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>24-72 hrs</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>4-7 days</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* Intracranial pressure (ICP) monitoring carried out in a total of 31 patients.

**TABLE 3**
Appearance of CSF spaces on initial CT scan*

<table>
<thead>
<tr>
<th>3rd Ventricle Visible</th>
<th>Basal Cisterns Visible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>no</td>
<td>50</td>
</tr>
<tr>
<td>yes</td>
<td>6</td>
</tr>
</tbody>
</table>

* CSF = cerebrospinal fluid; CT = computerized tomography.

two had a lobectomy for increasing mass effect in association with local contusions. The remaining four patients, who had a very thin subdural hematoma, underwent craniotomy in an effort to control rising ICP in association with clinical deterioration; in each the subdural hematoma was confirmed to be thin and insufficient to account for the patient's condition.

**Neurological Deterioration**

Overall, 41 (35%) of the 118 patients deteriorated. This was somewhat more frequent in adults, 24 of whom deteriorated as compared with 17 children. Deterioration occurred within 24 hours of injury in 24 patients, within 3 days in a further 13, and by the 7th day in the remaining four. The timing and mode of deterioration are illustrated in Table 4 separately for the adult and children.

The risk of deterioration was much higher in patients with prolonged coma and also in those who had an episode of hypotension (Table 5). Coma for more than 1 hour was the most common single feature associated with subsequent deterioration both in adults and in children. In each age group, several patients deteriorated in more than one feature. Focal signs alone occurred only in children and elevated ICP alone in adults, but each in only three cases. The risk of deterioration was also increased by approximately twofold in patients whose basal cisterns were not seen on the first CT scan (Table 5) or who had subarachnoid or intraventricular hemorrhage. Patients with lesions suggestive of diffuse axonal injury deteriorated twice as often, but this did not reach statistical significance.

**Outcome**

Outcome, assessed by the GOS, was better in children, 46 (78%) of whom made a moderate or good recovery, as compared with 24 (41%) adults (Table 6). Outcome was worse in the 41 patients who suffered deterioration; of these, 33 died, three were severely disabled, and only five made a moderate or good recovery. None of the 77 patients who did not deteriorate died, but three were left vegetative and six were severely disabled. Sixty-two patients were ventilated or given mannitol, steroids, or furosemide. Overall, the outcome in this group was worse; only 26% had a favorable outcome and 50% died, but this group also included the most severely injured patients.

**Discussion**

This report is the largest detailed study of patients with CT signs of diffuse brain swelling. In the light...
of its findings and results of previous reports, we can consider some of the outstanding clinical questions about diffuse traumatic brain swelling. How do patients with diffuse swelling compare with patients who have sustained other head injuries? How do adults and children with diffuse brain swelling compare? What is the risk of deterioration and poor outcome in these patients, and what factors predict this? It is necessary first to consider how the diagnosis of diffuse brain swelling should be made.

**Diagnosis of Diffuse Swelling**

The population in this study was defined by clear criteria applied by an experienced neuroradiologist, which led to a consistency in the diagnosis of brain swelling. In some previous studies the diagnosis was made on a subjective assessment of the lateral ventricles and or basal cisterns. However, this is an unreliable index of brain swelling; assessment of the CSF space is very subjective and shows considerable observer variability (CA Dolinas, unpublished data). In a report of 753 patients by Eisenberg, et al., 245 considered to have “small” ventricles did not have an increased incidence of raised ICP or a poor outcome. A diagnosis of swelling cannot be made reliable on the appearance of “compression” of the basal cisterns or third ventricle because this appearance can be difficult to assess consistently. We believe that, although preceded by narrowing or compression, a diagnosis of diffuse brain swelling should be made when either the third ventricle or the basal cisterns cannot be distinguished. A similar approach was employed by Eisenberg, et al., who showed a threefold increase in elevated ICP with obliterated basal cisterns. In addition, they were able to demonstrate that obliterated basal cisterns were an independent index of outcome after an acute head injury. This group also emphasized the association between hypoxia and hypotension and diffuse brain swelling, and postulated that such extracranial insults may be a cause of diffuse swelling.

**Patients With Diffuse Brain Swelling**

Previous reports have stressed the occurrence of diffuse swelling in children. Classically, this finding involves rapid deterioration, sometimes self-limiting but at times progressing to coma and death, the so-called “malignant brain swelling.” Adults have been considered more likely than children to develop unilateral swelling, often in association with an extracerebral hematoma. Children make up some 22% to 25% of all head-injury admissions to our unit and 15% to 18% of those with a severe injury. Our finding of equal numbers of children and adults with brain swelling indicates that the former are more likely to have diffuse swelling. On the other hand, the adults were at a higher risk of secondary deterioration.

The majority of patients in this series had clinical or radiological evidence of primary brain damage. As a group, they were more severely injured than the overall cases of head injuries sent to our unit; of these patients with diffuse swelling, 75% were injured in a high-velocity road-traffic accident compared with only 38% of all patients with head injuries admitted to our neurosurgical department. Similarly, 75% of patients with diffuse swelling were in coma when admitted, whereas this is the case in only 25% of head-injury admissions in the Glasgow Neurosurgical Unit.

In the series of children reported in 1981 by Bruce, et al., there was a similarly high proportion of patients in coma. By contrast, Snoek, et al., stressed that children who deteriorated as a result of brain swelling had usually sustained a minor head injury without significant distribution of consciousness. However, in that series many patients did not undergo CT so it is impossible to know the number of patients who fulfilled the radiological criteria for diagnosis of diffuse brain swelling. The CT scan showed features of additional injury in the majority of our series but, in 60% of the children, CT showed only signs of swelling. This is in contrast to the study of Cordobés, et al., in which 11 of 18 children had deep parenchymal lesions or subarachnoid hemorrhage; this finding was associated with raised ICP that could not be controlled medically. More than one-half of their patients died.

Systemic complications were frequent in patients with diffuse brain swelling, even though clinical records probably greatly underestimate the frequency of such insults. One in five patients had been hypotensive, and a similar proportion had a hypoxic insult. This is comparable with the report of head-injured patients transferred to the neurosurgical unit in Glasgow. The relationship between systemic insults and diffuse brain swelling has recently been considered by Eisenberg, et al. They found that prehospital hypoxia and hypotension was associated with an increased incidence of diffuse swelling. Our study showed in addition that the occurrence of either insult was more common in patients who deteriorated after a diagnosis of diffuse brain swelling had been made.

**Diffuse Swelling in Different Age Groups**

The pattern of findings was broadly similar in adults and in children, but with some important exceptions. Adults were more likely to have evidence of severe initial injury; twice as many had extracranial injuries, and three times as many had been shown by CT to have signs of diffuse axonal injury. The level of consciousness on admission was similar in both age groups, although adults showed secondary deterioration some-
Diffuse brain swelling after head injury

what more often, especially in consciousness level. This was reflected in adults being twice as likely to have a poor outcome.

These observations suggest that a child's brain may more readily respond to injury by developing diffuse swelling, and the corresponding CT changes may appear more readily because children have a proportionately greater intracranial CSF volume available for displacement. In children, the swelling appears to be benign in more than 75% of cases, whereas in adults its appearance signifies a poor outcome in two-thirds of cases.

Neurological Deterioration

Deterioration occurred in 35% of cases in the series reported here. It was more frequent in adults (41%) than children (29%) but in both groups it led to a high mortality rate. The features of patients liable to deterioration were similar in both age groups. They had usually sustained a severe high-velocity injury and on CT showed evidence of severe primary brain damage with additional signs of subarachnoid hemorrhage. It was notable that secondary deterioration after CT occurred only once in a patient who had not been initially unconscious. This patient subsequently recovered. Eisenberg, et al. showed that, in patients in coma, those who had sustained either hypoxia or hypotension were more likely to have CT appearances of diffuse swelling. Our study demonstrates that, in addition to increasing the frequency of swelling, these extracranial insults increase the risk of deterioration and poor outcome in patients with brain swelling. Although hypotension was recorded in less than one-half of the patients who deteriorated, it may have been present in other cases but unnoted because of failure to detect episodes occurring before or between monitoring.

Pathophysiology

Many believe that diffuse swelling represents a physiological response to trauma and is produced mainly by vascular engorgement. The causes of such engorgement remain obscure. It may be related to the mechanism rather than the degree of injury, because the present study shows that swelling is seen in patients with a wide spectrum of initial severity. Defective autoregulation, altered cerebrovascular tone, and hypoxemia secondary to systemic shock, hypoxia, and seizures have each been implicated. There are, however, doubts that engorgement per se can cause persisting elevation of ICP. Diffuse bilateral swelling may be a different phenomenon to the unilateral swelling commonly seen in association with an intracranial hematoma in which the predominant mechanism may be ischemic edema. Patients with diffuse swelling who deteriorate may have developed true edema superimposed upon hyperemia.

Outcome and Management

Sixty percent of the patients had a moderate or good outcome at 6 months. In previous series, the risk of deterioration and poor outcome has ranged from less than 10% to as high as 50%. Our findings have important implications for the care of head-injured patients. The importance of extracranial insults, both in promoting diffuse brain swelling and in leading to subsequent deterioration and poor outcome, emphasizes the need for prompt and effective initial resuscitation. It underlines the priority to be given to the identification and treatment of extracranial injuries that might lead to hypoxic or hypertensive insults becoming superimposed upon severe initial primary brain damage.

The optimum treatment of patients with diffuse brain swelling remains to be determined. Methods advocated included hyperventilation, somatic therapy, diuretic agents, and barbiturates. Comparison with results from different series is difficult because of the variable criteria used for the diagnosis and the lack of controlled studies. When this retrospective series of patients was treated, management focused on maintenance of systemic arterial perfusion pressure and oxygenation, hence avoiding systemic changes that are believed to promote or exacerbate intracranial vascular dilation, swelling, and raised ICP. There was selective, restricted use of ventilation, administration of mannitol and diuretic agents, and measurement of ICP, reflecting the varying views of European neurosurgeons about the indicators for these interventions. These methods are now being used more frequently in our unit, and comparisons of this retrospective series with the findings and outcome in current series will be of interest.

Improved management of diffuse swelling after head injury may depend on better methods of diagnosis and monitoring. The ability to distinguish between engorgement due to hyperemia, to increased water content, or to infarction would aid understanding and treatment. Analysis of ICP data may distinguish "vascular" and CSF components; such indices may usefully guide management but are not directly equated with the concepts of hyperemia and edema. It may be possible to separate these mechanisms by means of neuroimaging with either CT or magnetic resonance (MR) imaging. When cerebral blood volume was measured with the aid of contrast-enhanced CT, we did not find a correlation with ICP in patients with either focal or diffuse head injury. The MR signal is more closely related to tissue water content than are CT Hounsfield units. Although accurate measurement of relaxation times is difficult in clinical circumstances, a method capable of direct extrapolation has recently been developed by Marmarou, et al. This group has also determined cerebral blood volume from xenon-CT measurements of cerebral blood flow (CBF) and transit time focus; a correlation was found between cerebral blood volume and the pressure volume index but not the ICP. Magnetic resonance indices of tissue perfusion and water diffusion are being developed and may prove informative; MR imaging is a more sensitive detector of primary brain damage than is CT and may provide more understanding of the role of diffuse initial injury in the patient with diffuse swelling. Progress may come
from focusing on the identification of patients at high risk of deterioration: these include patients in sustained coma, those who have had an episode of systemic shock or hypotension, or those whose initial CT scan shows evidence of diffuse primary injury.

Conclusions

Diffuse brain swelling occurred in patients with a wide range of initial severity of injury and affected an equal number of children and adults admitted to the neurosurgical unit. When diffuse swelling was observed in patients without prolonged initial unconsciousness, the risk of subsequent deterioration was very low (4%) and, in such patients, monitoring of ICP and other aspects of intensive management may be unnecessary. By contrast, in patients who had persisting coma (> 1 hour), the risk of deterioration was extremely high (77%). Patients who deteriorated also showed more abnormalities on the initial CT scan (lesions of diffuse shearing injury, subarachnoid hemorrhage) and often had sustained a systemic insult, especially hypotension. The extent to which outcome in such patients is affected by current management is unclear. Despite the controversy about the value of ICP monitoring, its measurement with the assessment of cerebral perfusion pressure and cerebral metabolism may be justified in this selected group of high-risk patients. These assessments should be coupled with endeavors to establish the mechanism of swelling and its optimum response to different methods of treatment.

References


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