Prognostic Value of CT in Head Injuries

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Summary

Five hundred cases of acute head injury were analyzed on the basis of clinical severity, CT findings and outcome. Parenchymal lesions, which were the most important information in predicting the outcome, were classified into six categories: Isodensity WITHOUT Mass Effect, Isodensity WITH Mass Effect, High Density, High and Low Density Complex, Low Density, and Acute Diffuse Cerebral Swelling. Isodensity WITH Mass Effect was related to the worst outcome (59% mortality and 24% functional recovery). This finding was obtained 2 and a half hours following trauma and High and Low Density Complex eventually appeared in repeated CT.

Epidural hematoma was associated with parenchymal lesions in only six (40%) out of 15 cases and acute subdural hematoma was accompanied by parenchymal lesions in 21 (84%) out of 25 cases. The remarkable differences in the outcome of those two extracerebral hematomas were entirely dependent on the associated parenchymal lesions.

In the minor head injury group, parenchymal lesions were not rare (8.5%) in patients with a loss of consciousness even for a brief period.

To follow the rapid dynamic changes in parenchymal lesions, the importance of repeated CT was emphasized.

Key words: Computerized tomography, head injury, cerebral contusion, epidural hematoma, subdural hematoma

Introduction

In predicting the outcome of head injuries, the most important information undoubtedly concerns the parenchymal condition. No other diagnostic measure was able to visualize parenchymal lesions in life (in-vivo clinical-pathological correlation) until the introduction of computerized tomography (CT). Analyzed here are 500 cases of acute head injury, observed by CT, including minor and severe head injury groups. Stress is placed on analysis of the prognostic value of CT findings.

Materials and Methods

This analysis was conducted on 500 cases of head injury treated in the Chiba University Hospital and two affiliated hospitals, for a period of 18 months up to August, 1979. Surgical policy and adjunctive therapy of head injuries were uniform. To decompress increased intracranial pressure, a large decomplicative craniectomy was the method of choice. Mannitol was used only in a single dose while waiting for surgery. Steroid was used pre- and postoperatively in the usual doses. The three hospitals were equipped with two EMI 1010 and one ACTA 0200FS.

CT was carried out as soon as possible on arrival of the patients and most of the initial CT was carried out within 48 hours of the head injury. To determine the dynamic changes in parenchymal lesions, CT was deliberately repeated in the severe head injury group.

Severity of the head injury was classified into four grades according to Araki and was also shown by the Glasgow Coma Scale. The former is a very practical classification based
on the clinical course and is widely used in Japan: (1) 'simple type' (no loss of consciousness, no neurological deficit), (2) 'transient type' (loss of consciousness for less than 6 hours, no neurological deficit), (3) 'prolonged type' (loss of consciousness for more than 6 hours), and (4) 'worsening type' (deteriorating). The latter two types are referred to as severe head injuries in this analysis and the former two types as minor head injuries.

CT findings were recorded in our own protocol with other clinical information. The CT was read for each structure of the head: a) extracranial, b) cranial, c) epidural, d) subdural, e) subarachnoid, f) ventricular, and g) parenchymal. The classification of the parenchymal lesion is the most crucial point in this study because the gravity of head injury is entirely dependent on the injury of the brain itself. Parenchymal lesions were classified into six categories (Table 1).

1) **Isodensity WITHOUT Mass Effect**: Density is normal and there is no evidence of swelling of the brain as far as can be seen from the shape and the size of the ventricular system or the subarachnoid spaces.

2) **Isodensity WITH Mass Effect**: Density of the parenchyma is not different from that of the normal brain, but the deformity and shift of the ventricular system and the obliteration of cerebrospinal fluid (CSF) spaces are evidence of local or hemisperic cerebral swelling (Fig. 1).

3) **High Density**: Discrete spherical high density which may be surrounded by a low

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### Table 1 Classification of parenchymal lesions

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isodensity without mass effect</td>
</tr>
<tr>
<td>Isodensity with mass effect</td>
</tr>
<tr>
<td>High density</td>
</tr>
<tr>
<td>High and low density complex</td>
</tr>
<tr>
<td>Low density</td>
</tr>
<tr>
<td>Acute diffuse cerebral swelling</td>
</tr>
</tbody>
</table>

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Fig. 1 Acute subdural hematoma and Isodensity WITH Mass Effect on the left side. 41 year old male (dead). CT 5 hours and 15 minutes after trauma.

Fig. 2 High Density. Discrete High Density lesion is surrounded by a low dense halo at the top (12 hours after trauma) of the figure. 48 year old male (good recovery).
dense halo with a time elapse from impact (Fig. 2).

4) **High and Low Density Complex**: Small and large high density and low density areas are intermingled in a single lesion (Fig. 3). “High Density” and “High and Low Density Complex” are based on what the observer sees in CT films and not related to the pathogenesis of such phenomena. Such terminology as ‘contusion’ or ‘hemorrhagic contusion’ is intentionally avoided. The ratio of the size of high and low density areas is variable and all varieties of high and low densities are included in this category.

5) **Low Density**: Low density area with no high density components.

6) **Acute Diffuse Cerebral Swelling**: As defined by Zimmerman et al., the brain is swollen bilaterally and equally, and the ventricular system and the CSF spaces have collapsed. The parenchymal density is within the normal range in ordinary CT films.

The patients were followed-up for periods of 12 months to 26 months in this series. The outcome was indicated by the Glasgow Outcome Scale and the prognostic value of CT in the acute stage of head injury was evaluated. ‘Functional Recovery’ is defined as good recovery and moderately disabled in the Glasgow Outcome Scale.

**Results**

The present series is composed of 500 patients with acute head injuries of various severities. Two hundred and fifty nine were in the category of the ‘simple type’, 130 of the ‘transient type’, 65 of the ‘prolonged type’ and 46 of the ‘worsening type’ according to Araki. The former two types, the minor head injury group, and the latter two types, the severe head injury group, are discussed separately. In the severe head injury group, 108 cases were adequate for analysis of parenchymal lesions.

A) **Extracranial structure**: Subgaleal hematoma is not only evidence of trauma, but also points to the site of impact. Epidural hematoma just beneath the subgaleal hematoma and parenchymal lesions with acute subdural hematoma on the opposite side of the impact were common findings, suggesting coup and contrecoup injuries.

B) **Cranium**: Depressed fractures at the convexity and free fragments in the parenchyma could be observed in ordinary CT films. Window level and width should be arranged to look for a minor bony injury, but CT was often not as helpful as plain skull films. Also attention was paid to the base of the skull, including the orbit, the paranasal sinuses and the petrous bone. Air from the basal skull fracture was quite easily recognized in each intracranial compartment even if the amount of air was very small, but the entrance of air or exit of CSF leakage was usually quite difficult to determine. The cortical injury beneath the depressed bone fragments was also difficult to identify until the fragment was removed.

C) **Epidural abnormality**: Epidural hematoma was observed in five cases (1.3%) in the minor head injury group and 15 cases (13.5%) in the severe head injury group. The other four cases of the latter group possessed both of epidural hematoma and acute subdural hematoma. Concomitant parenchymal lesions were observed in only six out of 15 cases. This was reflected in their outcome which was quite favorable since useful recovery was achieved in 11 cases (73%) and only two cases (13%) died.

D) **Subdural space**: Acute subdural hematoma was observed in only three cases (0.8%) in the minor head injury group and in 25 cases (23%) in the severe head injury group. Parenchymal lesions were associated with 21 (84%) out of 25 such cases. Among the parenchymal
lesions, Isodensity WITH Mass Effect was the most common finding, observed in 15 cases, followed by High Density or High and Low Density Complex in six cases. Acute subdural hematoma in the severe head injury group had a poor outcome; only 11 cases (44%) achieved functional recovery and 13 cases (52%) died. Mortality of acute subdural hematoma has been rather high since before CT appeared.\(^8\)\(^,\)\(^13\)\(^,\)\(^20\) The authors have reported that the reason for such a high mortality is the presence of the parenchymal lesions.\(^33\)

On three occasions, the development of chronic subdural hematoma was observed in repeated CT (Fig. 4). The initial CT showed bilateral subdural collections of low dense fluid in the acute stage of the head injury. Such collections were not homogenous in density but high and low density components were mixed as if a clot and CSF were present in layers. After several weeks, this fluid collection changed into a typical isodense chronic subdural hematoma which required surgical evacuation. All three patients were in their seventies.

E) Subarachnoid space: Observations of the cortical sulci, Sylvian fissure, interhemispheric fissure and basal cisterns offer very important information in predicting the outcome. Abnormalities are clots of high density and deformity or obliteration of subarachnoid spaces. A subarachnoid clot was rarely (0.5%) observed in the minor head injury group but was seen in as many as 25 cases (23%) in the severe head injury group. Their Glasgow Coma Scale was 5.4 ± 2.5 (3–11) and parenchymal lesions, Isodensity WITH Mass Effect and High and Low Density Complex were seen in all but three cases (12%). The outcome was poor with functional recovery in only six cases (24%) and death in 15 cases (60%). Five cases were associated with ventricular hemorrhage, resulting in death in four cases and a persistent vegetative state in one case.

Compression or obliteration of the basal cistern is a sign of poor outcome. The basal cistern was observed in two compartments, one anterior to the brain stem and the other posterior to the brain stem. Obliteration of the anterior basal cistern is associated with a mortality of 59%, and the posterior basal cistern is associated with a mortality of 72%. As long as the basal cistern was clearly visualized in CT, their chance of functional recovery was more than 70%. When the Sylvian fissure was obliterated bilaterally in adults, 54% died and 33% achieved functional recovery. When the Sylvian fissure was opened bilaterally, 15% died and 73% achieved functional recovery.

F) Ventricular system: CT shows the influence of mass from deformities, obliteration, shifts of the ventricular system and the presence of blood in various compartments of the ventricular system.

Ventricular hemorrhages were seen in eight cases (7.4%) in the severe head injury group.

![Fig. 4](image-url) Development of isodense chronic subdural hematoma on the left side (62 days after trauma, the bottom of the figure) from subdural hygroma (2 days after trauma, the top of the figure). 74 year old male (good recovery).
and they were all observed within 48 hours of the head injury. Seven cases were associated with parenchymal lesions of High Density and High and Low Density Complex. Their Glasgow Coma Scale was $6.2 \pm 2.2$ ($3 \sim 9$) in the presence of ventricular hemorrhages and the outcome was death in seven and a persistent vegetative state in one case.

**G) Parenchyma**

1. Minor Head Injury Group: Included here are 389 patients who did not lose consciousness or became conscious after a brief period of unconsciousness. None of them had neurological deficits initially. However, 15 (3.9%) of them possessed unexpected parenchymal lesions (Table 2, Fig. 5). Once a patient loses consciousness by a trauma, even if it is a very brief episode, the chance of parenchymal lesions is 8.5%, which can not be neglected in practice. Parenchymal lesions were High Density or High and Low Density Complex, and on no occasion was there Isodensity WITH Mass Effect which was the most dismal sign for the severe head injury group.

2. Severe Head Injury Group: Dynamic changes of parenchymal lesions. The brain shows very dramatic and dynamic changes in CT observations (Fig. 6). Immediately after impact, when there is no chance of CT from a practical point of view, the density of the brain should be within the normal range. Then the brain shows 'swelling', which may be focal, hemispheric, or diffuse, but the density remains normal for various periods. In this swollen brain, High Density or High and Low Density Complex appears in several hours or days, which turns into Low Density in approximately 3 weeks. This observation is a prototype of brain injury. Some cases may be lost at some point in this natural course after rapid deterioration and also others may be observed only in the latter part of the course.

(Isodensity without Mass Effect) Although the unconsciousness continued for more than 6 hours or even deepened, the brain did not differ from the normal state in 46 (43%) out of 108 cases. Extracerebral hematomas were present in 28%. There were nine epidural

### Table 2

<table>
<thead>
<tr>
<th>Classification by Araki</th>
<th>I</th>
<th>II</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracerebral</td>
<td>259</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Epidural</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Subdural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High dense</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Iso dense</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Low dense</td>
<td>9</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>13 (5.0%)</td>
<td>10 (7.7%)</td>
<td>23 (5.9%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parenchymal</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>High density</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>High &amp; low density</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Low density</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Diff CBR swelling</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 (1.5%)</td>
<td>11 (8.5%)</td>
<td>15 (3.9%)</td>
</tr>
</tbody>
</table>

I: Simple type, II: Transient type.

![Fig. 5 Unexpected parenchymal lesion (High and Low Density Complex) in the right Sylvian area following a minor head injury. 69 year old female (good recovery). CT 1 hour after trauma.](image)
hematomas and four acute subdural hematomas. After an initial CT of Isodensity WITHOUT Mass Effect, repeated CT was carried out in 18 cases. Parenchymal lesions of High Density or High and Low Density Complex appeared in three of the 10 non-operative cases and in four of the eight operative cases. Their prognosis was favorable; functional recovery was achieved in 37 cases (80 %) and only seven patients (15 %) died. 

<Isodensity with Mass Effect> This finding was observed in the initial CT of 17 cases (16 %) and only seven patients (15 %) died.

Table 3 Isodensity with mass effect

<table>
<thead>
<tr>
<th>Patients</th>
<th>17 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>34.2 ± 20.3 (3~79) yrs</td>
</tr>
<tr>
<td>Time</td>
<td>11 cases (65%) within 3 hr</td>
</tr>
<tr>
<td></td>
<td>15 cases (88%) within 6 hr (mean: 2 hr 37 min)</td>
</tr>
<tr>
<td>GCS</td>
<td>5.2 ± 2.0</td>
</tr>
<tr>
<td>Operation</td>
<td>14 cases</td>
</tr>
<tr>
<td>Repeated CT</td>
<td>1</td>
</tr>
<tr>
<td>I (-)</td>
<td>1</td>
</tr>
<tr>
<td>I (+)</td>
<td>2</td>
</tr>
<tr>
<td>H</td>
<td>0</td>
</tr>
<tr>
<td>H-L</td>
<td>7</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
</tr>
<tr>
<td>Outcome</td>
<td>GR 3, MD 1, SD 0, V 3, D 10</td>
</tr>
</tbody>
</table>

Repeated CT was carried out in 12 cases and High and Low Density Complex appeared in seven cases. High Density was not observed in any case. Only one of them returned to Isodensity WITHOUT Mass Effect. The age was distributed between 3 and 79 years (mean: 34.2±20.3 years).

<High Density and High and Low Density Complex> High Density and High and Low Density Complex were quite similar phenomena in that the incidence was 11% and 18%, the mortality 42% and 37%, the chance of functional recovery 50% and 53%, the Glasgow Coma Scale 7.6±3.5 and 8.5±3.9, and the mean age 45 years and 43 years, respectively. They differed only in the time interval after head injury. High Density was observed within 6 hours of impact and High and Low Density Complex between 6 hours and 24 hours after head injury. High Density was surrounded by a low density halo in the following course, but this was not read as High and Low Density Complex.

Complicated classification of parenchymal lesions with high dense components was avoided here, and our classification into two unequivocal categories is quite simple to facilitate wide practical use and minimize observer variabilities. Recording the lesion as 'single' or 'multiple' was also an unequivocal matter. There were remarkable differences in the outcome between single and multiple lesions. Multiple lesions, no matter where the lesions were located in the unilateral hemisphere or in the bilateral hemisphere, showed a much higher mortality (Table 4).

In two children, there was a single lesion of

Table 4 High density and high-low density

<table>
<thead>
<tr>
<th>Patients</th>
<th>12</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>44.8 ± 22.1 yrs</td>
<td>43.2 ± 20.7 yrs</td>
</tr>
<tr>
<td>Time</td>
<td>0~6 hr</td>
<td>6~24 hr</td>
</tr>
<tr>
<td>GCS</td>
<td>7.6 ± 3.5</td>
<td>8.5 ± 3.9</td>
</tr>
<tr>
<td>Operation</td>
<td>6 (50%)</td>
<td>8 (42%)</td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>1/7 (14%)</td>
<td>3/12 (25%)</td>
</tr>
<tr>
<td>Multiple</td>
<td>4/5 (80%)</td>
<td>4/7 (57%)</td>
</tr>
<tr>
<td>Total</td>
<td>5/12 (42%)</td>
<td>7/19 (37%)</td>
</tr>
</tbody>
</table>
High Density and High and Low Density Complex at the basal ganglion in each case. These children showed hemiparesis which gradually improved. This isolated lesion in the basal ganglia seems to have a unique clinical picture (Fig. 7). Angiography failed to show any abnormality.

〈Low Density〉 In acute stages of head injury, Low Density lesion with no high dense components was rare and seen in only four cases. All parenchymal lesions, associated with considerable destruction of brain tissue, are destined to end in Low Density. Such an end stage should not be confused with the phenomena in the acute stage. Low Density in the posterior cerebral artery distribution, as a consequence of infarction due to transtentorial herniation, is a common finding in the severe head injury group, but is not included in this category.

〈Acute Diffuse Cerebral Swelling〉 Acute Diffuse Cerebral Swelling was observed in the initial CT of 10 patients (9%). Six of them were findings within 6 hours of impact. The outcome of such patients was clearly divided into two categories, favorable (good recovery in six and moderately disabled in one) and quite dismal (death in three). All deaths were within 3 hours to 15 hours of head injury (Fig. 8). At the present time, there are no recognizable differences in CT findings between the above two groups. In the benign group, the ventricular system returned to the normal size in 5 to 15 days (mean: 9 days) in repeated CT.

The outcome in each parenchymal lesion is summarized in Table 5.

Discussion

The role of CT in the study of acute head injuries has been highly evaluated. There have been many reports on CT observation of head injury, but papers on the prognostic value of CT are limited. Our attention was focused on the relation between the parenchymal lesions and the prognosis. CT also disclosed unexpected lesions in the minor head injury group which could not be detected in vivo before CT.

To obtain as much information as possible from any single CT film, a protocol was

![Fig. 7](image_url)  
**Fig. 7** A single isolated parenchymal lesion (High and Low Density Complex) at the left basal ganglion. 6 year old male (moderately disabled). CT 7 days after trauma.

![Fig. 8](image_url)  
**Fig. 8** Acute Diffuse Cerebral Swelling. 20 year old female (dead). CT 1 hour and 30 minutes after trauma.
prepared to record all abnormalities in each structure of the head. The recording sequence was as follows: extracranial soft tissue, cranium, epidural and subdural spaces, subarachnoid spaces, ventricular system and parenchyma.

**Extracranial structure** CT is very sensitive to abnormal densities of the extracranial soft tissue. The most common abnormality at this site is a subgaleal hematoma which is definite evidence of impact and which reveals much about the possible mechanism of brain injury. When the parenchymal lesion was unilateral, differentiation of a coup or contre-coup injury was apparent in a single CT film.

**Cranium** CT disclosed the accurate location of free bone fragments in the parenchyma or a significant injury of the brain beneath a depressed fracture, but the use of CT for diagnosis of linear fractures of the convexity or basal skull fractures was of limited value.

**Epidural abnormality** The true incidence of epidural hematoma was not known until the introduction of CT. In minor head injuries with no neurological deficits, angiography was rarely carried out and asymptomatic epidural hematoma was not noticed. CT in minor head injuries was reviewed for this purpose, and epidural hematomas were found in only 1.3% of the 389 cases. This incidence is fairly low compared with 4.6% for subdural abnormalities.

In the severe head injury group, the incidence of epidural hematoma was 13.5% and parenchymal lesions were present in only six out of 15 cases. This is the reason for favorable recovery from epidural hematoma in 73% of the cases. It is important to know that contusions of the cerebral cortex just beneath the depressed fracture or the massive epidural or subdural hematoma, both of which are significantly high dense, might not appear in CT. Becker et al.2) stressed the importance of direct inspection of the subdural space and over the cortex through a small dural opening during surgery even if an epidural hematoma is definitely confirmed in CT. Isodense epidural hematomas have been reported.2,1) Loss of red blood cells into the other injury site is the cause of this unusual density of hematoma.

**Subdural space** Subdural abnormalities are controversial even in CT. It is difficult to know whether subcranial low density, particularly in children, is a subdural space or a subarachnoid space in a plain CT. Metrizamide cisternography is indicated in such cases. Subdural collection in children shows a benign natural history and a spontaneous regression can be expected in most of the cases.1,2)

Acute subdural hematoma was associated with significant parenchymal lesions. The most common lesion is Isodensity WITH Mass Effect with a high mortality. Diagnosis of acute subdural hematoma is not difficult with CT because of its characteristic shape and wide extension, but underlying brain injury is often missed in CT. A normal looking brain with a hemispheric swelling is a sign of significantly poor prognosis. The outcome is entirely dependent on this brain injury, not on the presence of a subdural hematoma.3,3)

Chronic subdural hematomas developed in repeated CT based on the subdural hygroma in older patients. This observation was also confirmed by Yamada et al.3,2)

**Subarachnoid spaces** Blood clots in the

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Table 5 Incidence of parenchymal lesions and prognosis (initial CT)

<table>
<thead>
<tr>
<th></th>
<th>Number of patients</th>
<th>Functional recovery</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isodensity without mass effect</td>
<td>46 (43%)</td>
<td>37 (80%)</td>
<td>7 (15%)</td>
</tr>
<tr>
<td>Isodensity with mass effect</td>
<td>17 (16%)</td>
<td>4 (24%)</td>
<td>10 (59%)</td>
</tr>
<tr>
<td>High density</td>
<td>12 (11%)</td>
<td>6 (50%)</td>
<td>5 (42%)</td>
</tr>
<tr>
<td>High &amp; low density</td>
<td>19 (18%)</td>
<td>10 (53%)</td>
<td>7 (37%)</td>
</tr>
<tr>
<td>Low density</td>
<td>4 (4%)</td>
<td>2 (50%)</td>
<td>1 (25%)</td>
</tr>
<tr>
<td>Diffuse CBR swelling</td>
<td>10 (9%)</td>
<td>7 (70%)</td>
<td>3 (30%)</td>
</tr>
</tbody>
</table>

108 (100%) 66 (61%) 33 (31%)
various subarachnoid spaces were rarely observed in the minor head injury group but were seen in 23% of the severe head injury group. These findings were associated with a very grave clinical state, concomitant with parenchymal lesions and poor outcome.

Compression and obliteration of the basal cistern is known as one of the signs of descending transtentorial herniation. In our observations, patency of the posterior perimesencephalic cistern was more important for a better outcome.

Ventricular system CT was the first noninvasive method which allowed observation of ventricular hemorrhages in vivo. Ventricular hemorrhage was associated with parenchymal lesions and with a significantly poor prognosis in this series. In the literature, ventricular hemorrhage was seen in 3 to 9% of head injuries and Tsai et al. listed the corpus callosum, fornix, choroid plexus and remote intracerebral hematoma as sources of ventricular hemorrhage. This was also observed without concomitant parenchymal lesions in three out of six patients by Oliff et al., one out of three patients by Merino-de Villasante et al., and six of 17 patients by Tsai et al. French et al. and Roberson et al. found parenchymal lesions in high dense components in all of their cases. The outcome in the presence of ventricular hemorrhage was not so poor and development of hydrocephalus was not common in their experience.

Minor head injury group Minor head injury, defined as the 'simple type' without loss of consciousness or the 'transient type' with brief unconsciousness, might cause parenchymal damage. Parenchymal changes in such minor head injuries were also not known until CT. Sekino et al. mentioned brain injury associated with minor head injury, using clinical and experimental materials. In our series, 8.5% of the patients with transient loss of consciousness had parenchymal lesions of High Density or High and Low Density Complex. There was no case where Isodensity WITH Mass Effect was demonstrated. Waga et al. reported a case of a 20 year old man who had not lost consciousness where CT revealed marked swelling of a unilateral cerebral hemisphere beneath a thin acute subdural hematoma. This lesion was exactly the same as Isodensity WITHOUT Mass Effect in our definition. Such parenchymal lesions in the minor head injury group should be carefully observed for the possibility of foci of epilepsy. CT, at least at the present time, is unable to visualize a contusion which is limited to the cortex or a small lesion in the brain stem. It should be stressed that CT is not omnipotent.

Severe head injury group Parenchymal lesions in the severe head injury group are never static phenomena, but show slow or rapid dynamic changes as summarized in Fig. 6.

Isodensity without Mass Effect In spite of clinically severe head injuries, there were no definite parenchymal lesions in 43% of the severe head injury group, but seven out of 18 cases where there was opportunity to repeat CT showed the new appearance of High Density or High and Low Density Complex. Isodensity WITHOUT Mass Effect was followed by a favorable outcome.

Isodensity with Mass Effect Only one fourth of such cases returned to a useful life in the presence of this parenchymal lesion. This most important parenchymal lesion was not well defined before. In initial CT in the acute stage (about 2 and a half hours after trauma), the density of the parenchyma is within the normal range in print-out data. The swelling is remarkable, usually compressing or obliterating the ventricular system on one side. There are two possible mechanisms which cause of this phenomena. One is that small low density areas (edema?) and high density areas (petechiae?) are equally mixed and the size of each area is smaller than the size of CT resolution. If the areas of abnormal densities were larger, this could be read as a 'salt and pepper' appearance. The second possible mechanism is a marked increase of
the vascular bed, which could be an immediate or very rapid response to trauma. The latter mechanism is considered in Acute Diffuse Cerebral Swelling, which, however, was reported to have a rather favorable outcome in the pediatric age group. In our observations, approximately 60% showed remarkable high dense components in later CT and in only one case, the swelling subsided without leaving any organic lesion. This observation probably supports the former mechanism of admixture of small lesions below the level of resolution in CT.

**High Density, High and Low Density Complex** Zimmerman et al. classified high dense parenchymal lesions into hemorrhagic contusions, intracerebral hematomas and diffuse white matter shearing injuries. Tsubokawa et al. found three types; primary intracerebral hematoma, hematoma within contusion and contusional hematoma. The latter classification is based on a possible causative mechanism of high dense lesions. The pathogenesis is not clearly understood at present. Tsai et al. stated that differentiation of contusion, hematoma or edema is not 'clear cut' even in CT observations. We have avoided a complicated categorization based on unknown pathogenesis. The differentiation of single or multiple lesions was quite useful concerning predictive values. Multiplicity of lesions has not been stressed with respect to the prognostic value. Sweet et al. found a high mortality (70%) in patients with bilateral high dense lesions. Extracerebral hematomas were included in the high dense abnormalities in their series.

In 1978, Zimmerman et al. pointed out the presence of small high dense areas, scattered in the swollen brain in shearing injury. The hemorrhage was characterized located at the corpus callosum, corticomedullary junction, and superior cerebellar peduncle. Shearing injury is included in multiple High Density areas with a very high mortality in our series.

**Low Density** Low Density lesions without any high dense components were rare in the acute stage. Low dense areas, which were seen as a halo around the High Density, as a part of the High and Low Density Complex, or as an infarction of the posterior cerebral artery due to transtentorial herniation, were not considered under this title.

**Acute Diffuse Cerebral Swelling** There is no question in the diagnosis of this phenomena from its characteristic findings. Zimmerman et al. found a favorable outcome in such patients, but in our series, few cases of the fulminating type were included. At the present time, it is difficult to differentiate these two quite different conditions by CT. In Roberson's series, there were 10 cases (11%) of this phenomena in 95 cases and eight of them followed a benign course, but two were dead or severely disabled. Pathogenesis of this lesion was considered as a remarkable increase of cerebral blood volume. Obrist et al. confirmed an increase in cerebral blood flow by intravenous injection of Xe.

**Importance of repeated CT** For a full understanding of brain injury, CT should be carried out at the earliest possible time after trauma and should be repeated according to clinical conditions. New parenchymal lesions appeared in 16 cases (15%) of the severe head injury group. Four of them were in nonoperative cases and the other 12 cases were postoperative. The most common new findings were High and Low Density Complex, followed by High Density. Such postoperative High Density appeared between 3 and 6 hours after trauma. This timing is agrees with that of initial CT observations of High Density. Pathogenesis of High Density is probably not related to the surgical procedure.

The usefulness of repeated CT has been reported by many authors. French et al. found new lesions resulting from further progress of the previous lesion in 52% of their patients and Cooper et al. found them in 65%.

CT has brought us a considerable amount of information about intracranial lesions but CT is not 'omnipotent'. It is difficult to visualize small lesions at the cerebral cortex and the brain stem due to the partial volume phenomena and the limits of spatial resolution of the present CT. The size of the ventricular system might be seen as smaller than the true size. Ise et al. reported the importance of delayed blood flow observed in angiography in relation to poor outcome. This information is not obtained by regular CT. French et al. listed
posttraumatic vasospasm, venous sinus occlusion and carotid cavernous fistulas as information which is difficult to obtain by CT. 7)

References


