Brain Lesions Detected by CT Scans in Cases of Minor Head Injuries

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Summary
Since CT scans make it possible to demonstrate precise morphological and anatomico-pathological findings, small brain lesions are frequently found on CT scans, in spite of the short duration of unconsciousness after head trauma.

Thirty six out of approximately 500 cases which received CT examinations within two weeks after head injury were selected and analyzed. In these cases, almost all high or low density lesions were detected in the tip and/or base of the frontal and/or temporal lobes adjacent to the skull. Causes of the injury were traffic accidents (33.3%), falls on the floor or road (33.3%), and falls down stairs, out of beds, etc. (25.5%). Clinical manifestations before CT examinations were heaviness in the head or headache (36.0%), and nausea and vomiting (33.3%), but thirteen out of 36 patients had no symptoms or complaints. None of the 36 patients showed any neurological dysfunctions suggesting focal damages.

Fourteen of the above-mentioned 36 patients (38.9%) had skull fractures and the remaining 22 (61.1%) did not, and there was no significant difference between the two. On the contrary, the incidence of skull fractures in cases in which CT scans were normal was 12.4% which was significantly different from the figure of 38.9% in patients with fractures and CT abnormalities. It is inferred that the deformation of the skull at the time of impact is one of the important factors in the development of brain contusions.

To clarify the correlation between the duration of the initial unconsciousness and abnormal CT findings, 219 consecutive cases of head injuries underwent CT scans without considering their severity. Out of 171 patients who were conscious or lost consciousness in less than 10 minutes, 13 (7.6%) had small lesions in CT scans. Of 12 cases with a state of unconsciousness from 10 to 60 minutes in duration, three (25.0%) had abnormal CT findings. In all cases which were unconscious for more than 6 hours, brain lesions were detected by CT scans.

Key words: Minor head injuries, cerebral concussion, cerebral contusion, CT scan

Introduction
Before computerized tomographic scanning (CT scan) was used as a routine procedure for accurate morphological diagnosis in neurological and neurosurgical disorders, it was impossible to find small and asymptomatic brain contusions or intracerebral hemorrhages after head injuries, except for a small number of unusual cases.

By classical definition, “cerebral concussion” is used to indicate a temporal dysfunction of the brain without posttraumatic organic changes. There was almost no chance to perform postmortem examinations in cases of so-called fatal concussions. Therefore “cerebral concussion” is one of the generally accepted concepts which is not based on precise pathological observations in almost all cases. While CT scans make it possible to show anatomicopathological findings, it is frequently found that abnormalities in CT scans are detected even in those patients who are injured by minor head trauma and recover from the initial unconsciousness without any posttraumatic sequelae.

On the other hand, several publications\(^1,2,5,6\)
concerning animal experiments on blunt head injuries revealed that small brain contusions, and intracerebral and subarachnoid hemorrhages were found in animals which were defined as having simple cerebral concussions.

The purposes of this study were to clarify how many lesions of the brain are being detected by CT scans after minor or mild head injuries; to analyze the causative relationship between lesions and impact conditions, skull fractures, or duration of the initial unconsciousness; and to compare the clinical and experimental data.

**Summary of Head Injury Experiments Using Monkeys**

To investigate the human head injury impact tolerance, a series of head injury experiments was performed using 63 monkeys under conditions of translational and rotational acceleration impact using a head restraint mask with a broad contact area, and direct impact on the unrestrained head using a padded flat surface. The results of these experiments have already been published by the authors and colleagues.3,5,6

In the experiment using pure translational acceleration impact, the resultant average head acceleration ranged from 240 to 1,100 G., and its duration from 3 to 18 msec. Cerebral concussions occurred in all subjects associated with no visible brain damage.3

Under conditions of rotational acceleration impact using a head restraint mask, occipital or frontal impacts produced small contusions, and subpial and subcortical hemorrhages in 67% of the animals which recovered from the concussion. These lesions were found in the basal surface and tip of the frontal and temporal lobes, and in the parasagittal region. The resultant average head acceleration in this series was 500–1,000 G., and its duration ranged from 1 to 5 msec.6

Direct impact on the unrestrained head produced brain contusions and subarachnoid hemorrhages in 20% of the animals with cerebral concussions. The resultant average head acceleration ranged from 140 to 1,100 G., and the duration from 1 to 14 msec.5

Figure 1 shows the relationship between concussions and contusions, and the resultant average head acceleration and its duration in cases of occipital impact under conditions of rotational acceleration impact using a head restraint mask, and of direct impact on the unrestrained head. The plotted curve shows the cerebral concussion tolerance threshold although duration of the impact producing the contusion had a tendency to be shorter. It is suggested that the conditions which result in brain contusions are very close to those causing concussions in humans.

**Materials in the Clinical Study**

Of approximately 500 patients who received CT examinations within about two weeks after minor or mild head injuries clinically diagnosed as simple concussions in our hospital and four affiliated ones (Omori Red Cross Hospital, Atsugi Hospital, Fuji Central Hospital and Kambara Hospital), 36 patients accounting for 7.2% were selected and analyzed.

These 36 patients had obvious and definite brain lesions in CT scans although they were aware or unconscious for less than 10 minutes after the head trauma. They had common complaints such as heaviness in the head, headache, nausea and vomiting, and did not show any neurological signs suggesting focal brain damage.

Small lesions in the brain were usually
located in the tip or base of the frontal and/or temporal lobes adjacent to the skull as verified in the experimental observations. It is relatively difficult to define these small brain contusions and subcortical hemorrhages in CT scans due to the limitation of quality control and artifacts, and therefore, sequential CT examinations were carried out in almost all cases to determine whether abnormal findings were true lesions or artifacts. When a high density abnormality was observed near the skull as shown in Fig. 2, successive CT examinations were performed after several days. If the density decreased or the size of the high density area increased, the abnormality was defined as a true lesion. Low density lesions were judged to be true if they were observed in at least two scans performed at an interval of several days or if they were found intracortically.

To confirm the correlation between the duration of the initial unconsciousness after head injuries and the incidence of CT abnormalities, CT scans of 219 consecutive cases of acute head injuries regard less of their severity were investigated.

Results

I. Age and sex distributions
The age distribution of 36 cases as illustrated in Fig. 3 gave the same pattern as shown for usual head injuries. Males were three times more frequent than females which were similar in number to usual cases.

II. Causes of minor head injuries
Causes of head traumas in this series are shown in Fig. 4. Traffic accidents (33.3%), falls on the floor or road (33.3%) and falls down stairs, out of bed, etc. (25.0%) were the common causes of minor head injuries. It is noteworthy that falls were a major cause of such head injuries when compared with usual head injuries where traffic accidents were the most common.
Fig. 4 Causes of minor head injuries. It is distinctive that falls were remarkable when compared with the usual causes of head injury among which traffic accidents were the most common.

Table 1 Symptoms prior to CT examinations

<table>
<thead>
<tr>
<th>Table 1 Symptoms prior to CT examinations</th>
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<tbody>
<tr>
<td>None</td>
</tr>
<tr>
<td>Headache</td>
</tr>
<tr>
<td>Nausea, Vomiting</td>
</tr>
<tr>
<td>Hypersomnia</td>
</tr>
<tr>
<td>Convulsions</td>
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<tr>
<td>Others</td>
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III. Symptoms prior to CT examinations (Table 1)

Before CT scans carried out within a few days after the injury, initial symptoms and complaints were heaviness in the head or headache (36.0%) and nausea and/or vomiting (33.3%). Thirteen out of 36 patients (36.0%) had no complaints or symptoms. Early onset of convulsions and hypersomnia were observed only in children or infants.
Table 2  Lesions detected by CT scans in minor head injuries

<table>
<thead>
<tr>
<th>Lesions in</th>
<th>n =</th>
<th>Left</th>
<th>Right</th>
<th>Coup</th>
<th>Contre coup</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>16</td>
<td>6</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal</td>
<td>18</td>
<td>11</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Occipital</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td>21</td>
<td>17</td>
<td>21</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>36 cases</td>
<td>(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

( ): multiple

IV. Locations of the lesions

Locations of the lesions detected by CT scans after minor or mild head injuries are tabulated in Table 2. Nineteen percent of brain lesions followed by CT scans were located in the tip or base of the frontal and/or temporal lobes, which are shown in the first column of the table. Multiple lesions in the bilateral frontal tips were observed in two cases after frontal and temporal impact respectively. There was no significant difference between the incidence of lesions in the dominant and in the non-dominant hemisphere as shown in Table 2.

Frontal and temporal lesions were caused to the same degree by coup and contrecoup injuries. All occipital lesions were produced by coup injuries. The correlation between the sites of impact and lesions detected by CT scans is illustrated in Fig. 5. Frontal impacts caused coup injuries, i.e. lesions in the frontal and/or temporal lobes. Compared with cases of serious head injuries, it may be characteristic that contrecoup injuries in the occipital lobe were not observed in this series. Coup injuries were found in 70.0% of cases with temporal blows, while contrecoup injuries in the frontal and/or temporal lobes were observed in 75.5% of cases after occipital impact.

Concerning skull fractures (Table 3), only one case out of nine of frontal impact with brain lesions had a linear fracture, but approximately half of the patients with temporal and occipital impacts had fractures. Contrecoup lesions were found in three quarters of the patients with occipital impact. In 36 cases with brain lesions detected by CT scans, fourteen (38.9%) had linear fractures and the remaining 22 cases (61.1%) showed no fractures. This may mean that there is no relationship between the occurrence of brain lesions in minor head injuries and the incidence of skull fractures. The incidence of skull fractures in cases which showed normal CT scans was 12.4% and that in cases with brain lesions in CT scans was 38.9%. There was a significant difference between these values.

As mentioned above, minor brain contusions detected by CT scans even in concussive patients and our experimental studies suggested that concussion and contusion tolerance thresholds overlapped.

V. Duration of initial unconsciousness and incidence of lesions detected by CT scans (Table 4)

Finally, 219 consecutive cases of head injuries, regardless of severity, underwent CT examinations within several days after trauma to clarify
the correlation between the duration of initial unconsciousness and the incidence of brain lesions in CT scans.

Out of 171 patients who were alert or who lost consciousness for less than 10 minutes, 13 (7.6%) had lesions. One of the overestimating factors was the fact that the degree of their head injuries was at least as severe as that of patients visiting hospitals. This 7.6% is a very small number when compared with the results of our animal investigations. Brain damage difficult determined by CT examinations is usually located adjacent to the base of the skull.

Three (25.0%) out of 12 cases with a duration of unconsciousness from 10 to 60 minutes after injuries presented CT abnormalities. There was a significant difference between 7.6 and 25.0%. In addition, all cases which were unconscious for over 6 hours after head trauma had abnormal CT findings.

### Discussion

In the textbook “Head Injury”, Walker, mentioned that “in the eighteenth century, the term ‘concussion’ was introduced to designate a functional derangement of the brain, considered to be without organic damage. The term, however, has met with considerable antipathy by thinking scientists who have realized that it represents a condition that rarely, if ever, exists”. We have had scarcely any chance to perform postmortem examinations in concussive cases except in a few cases. Therefore, ‘cerebral concussion’ is a clinical concept and is not always based on pathological considerations. However, after CT scans became available for defining the accurate morphological and anatomicopathological lesions in central nervous system disorders, small lesions in the brain have been found in cases of ‘concussion’, i.e., Walker’s opinion is verified.

In our animal experiments to investigate human impact tolerance, subarachnoid, subpial, and subcortical hemorrhages were found in 57% of concussive subjects by rotational acceleration impact. This brain damage by frontal or occipital impact was located mainly in the tip and basal surface of the frontal and/or temporal lobes. Only a slight difference was noticed between the concussion and contusion tolerance thresholds as illustrated in Fig. 1. From the concussion tolerance in monkeys, the human head impact tolerance threshold was assessed by means of the dimensional analysis technique. It was deduced that the human contusion tolerance threshold has a close relation to the concussion threshold.

Among approximately 500 patients with minor head injuries, 36 cases which showed abnormal CT findings were found. Small lesions in the brain detected by CT scans were observed in the tip or base of the frontal and/or temporal lobes near the skull, which was similar to the results in animal investigations.

Age distribution of these 36 cases presented the same tendency as shown in cases of usual head injuries. This observation suggested that brain contusions after minor head trauma were not caused by fragility of the brain and the skull in young patients or atrophy of the brain in old ones.

The incidence of skull fractures in patients with abnormal CT scans (38.9%) was significantly different from that in patients without CT lesions (12.4%). It is obvious that skull fractures are due to deformation of the skull at the time of impact, and therefore, it is concluded that important factors producing brain contusions may be both the translational and rotational accelerations and also deformation of the skull.

Analysis of 219 consecutive cases where CT examinations were performed within a few days after the injury showed that thirteen (7.6%) out of 171 cases which were aware or unconscious for less than 10 minutes had small and asymptomatic brain lesions. Three out of

<table>
<thead>
<tr>
<th>Duration of LOC</th>
<th>n = Normal</th>
<th>Abnormal</th>
<th>%</th>
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<tbody>
<tr>
<td>0 ~ 10 min</td>
<td>171</td>
<td>13</td>
<td>7.6</td>
</tr>
<tr>
<td>10 min ~ 1 h</td>
<td>12</td>
<td>3</td>
<td>25.0</td>
</tr>
<tr>
<td>1 ~ 6 h</td>
<td>12</td>
<td>6</td>
<td>50.0</td>
</tr>
<tr>
<td>6 ~ 24 h</td>
<td>12</td>
<td>12</td>
<td>100.0</td>
</tr>
<tr>
<td>over 24 h</td>
<td>12</td>
<td>12</td>
<td>100.0</td>
</tr>
</tbody>
</table>
12 patients who were unconscious for 10 to 60 minutes showed brain damage. There was a significant difference between the incidence in the above-mentioned two groups. All patients who lost consciousness for over 6 hours presented abnormal CT findings.

The literature concerning the correlation between CT abnormalities and the severity of clinical symptoms is not always consistent. In 1976, Merino-de Villasante, and Taveras\(^4\), reported that there was generally a direct relationship between the severity of clinical presentation and the CT demonstration of the abnormality responsible for the clinical status from the evaluation of 100 consecutive cases of head trauma. In the group usually diagnosed as having cerebral contusions, 14 out of 20 cases (70.0\%) had abnormal CT scans, and in groups with alert consciousness or with a very brief of loss of consciousness, 3 out of 17 patients (15.3\%) had mild focal edema. Their findings were similar to our observations in spite of the somewhat different situations.

In the assessment of head injury, Araki's classification was widely applied in Japan and ‘cerebral concussion’ was defined as cases where the duration of the initial unconsciousness after the injury was less than 6 hours without posttraumatic damages suggesting focal brain lesions which were clinically diagnosed. This definition is quite conceivable since the incidence of brain lesions in patients who were unconscious for over 6 hours is significantly different from that in the group with a state of unconsciousness of less than 6 hours, as shown in Table 4. Out of consideration of 13 patients clinically diagnosed as simple concussions associated with small brain lesions, it can be concluded that careful attention should be paid even to patients with a short duration of unconsciousness, i.e. less than 10 minutes after the head injury.

**References**


