Maxillofacial fractures in patients with closed head trauma: prevalence and association with intracranial lesions.

Poster No.: C-1404
Congress: ECR 2015
Type: Scientific Exhibit
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Keywords: Trauma, Diagnostic procedure, CT, Emergency, CNS
DOI: 10.1594/ecr2015/C-1404

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Aims and objectives

In patients with head trauma, intracranial lesions which constitute determinant factors for their prognosis frequently coexist with maxillofacial fractures (1). Some maxillofacial fractures could impinge on oronasal airways or may prevent immediate intubation in critically-ill patients, which may worsen the outcome of patients with intracranial traumatic lesions. However, despite such high clinical importance, the relationship between maxillofacial fractures and intracranial traumatic lesions has received little interest in the literature.

The aim of this study was twofold:

1. To **determine the prevalence** of maxillofacial fractures on computed tomography (CT) in patients with head trauma, and
2. To **find and discuss any association** between the presence and the severity of the maxillofacial fractures, and the presence and the severity of the intracranial traumatic lesions.
Methods and materials

Patients

We retrospectively reviewed the records of all patients with the history of head trauma who were registered in the electronic radiological database of our institution, a major tertiary referral hospital in northeastern Japan, between the January 2009 and December 2013 (5 years). One thousand three hundred and five (1,305) consecutive patients (age range: 0-96 years, mean: 47.5 years) who underwent initial head CT within 24 hours after head trauma were included in this study.

Two neuroradiologists reviewed by consensus initial CT findings obtained within 24 h after onset and calculated and assigned CT scores (intracranial and maxillofacial scores) to each patient. The evaluation of the intracranial and the maxillofacial lesions were conducted separately.

CT evaluation of maxillofacial fracture

For the purpose of proper categorization of maxillofacial fractures, the maxillofacial regions were divided in the following three zones on CT: periorbital, midface and mandibular (Fig. 1 on page 6).

On multiplanar reconstruction (MPR) images including the axial, coronal and sagittal images; the periorbital zone was defined as region comprised between the roof and the floor of the orbit. However, temporal bone fracture was considered as skull base fracture, therefore, excluded in this evaluation. The midface was defined as region bellow the orbital floor excluding the mandible which as considered as a different zone.

We evaluated whether or not fracture was present in each zone. When the fracture line crossed two adjacent zones, it was counted as positive in both zones.

Maxillofacial score to evaluate the severity of maxillofacial fractures

We introduced a maxillofacial score that ranges from 0 to 3. A patient's score was a number of the three maxillofacial zones in which fracture is noted. Patients without maxillofacial fracture were scored 0.
Intracranial CT evaluation

For the intracranial region, the following five traumatic lesions with previously-demonstrated clinical significance were evaluated: status of basal cisterns, midline shift, subarachnoid hemorrhage and/or intraventricular hemorrhage (SAH/IVH), epidural hematoma (EDH); and the volume of the hemorrhagic mass (2, 3).

The basal cistern status was classified as normal, compressed, or absent. Midline shift was defined as displacement of the septum pellicidum in relation to the midline, and was recorded in millimeters. A midline shift > 5 mm was scored as present and a shift # 5 mm was scored as absent (2-5). SAH/IVH and EDH were classified as present or absent.

Hemorrhagic mass was defined as any intracranial hemorrhagic lesion other than SAH/IVH, including subdural hematoma, EDH, parenchymal hematoma, and hemorrhagic brain contusion (2, 3). The volume of hemorrhagic mass in each patient was calculated by digital measurement using a dedicated workstation by multiplying the sum area of hemorrhagic masses on each slice by the slice thickness (2, 3). The volume of hemorrhagic mass in each patient was graded as absent, <25 mL, or #25 mL (2, 3, 4).

Calculation of the Marshall and Rotterdam CT Scores to measure the severity of intracranial trauma

Among the above-mentioned five intracranial CT findings, status of the basal cisterns and the presence of a midline shift are included in both CT scoring systems. Whereas, the volume of the hemorrhagic mass is included only in the Marshall score, and the presence of SAH/IVH and EDH are included only in the Rotterdam score (Table 1 on page 6).

The Marshall score range from 1 to 6 (Fig. 2 on page 7), based on the three CT findings and/or the type of hemorrhagic mass management (surgical evacuation, yes/no) (2-4). Patients from whom any TBI-related lesion was removed surgically were assigned a score of 5 and those with hemorrhagic mass # 25ml who did not undergo surgical removal were assigned a score of 6, regardless of other CT findings (2, 4, 5).

The Rotterdam score (Table 2 on page 8) were calculated as fellows(2-4): a) basal cistern status was classified as normal (=0), compressed (=1), or absent (=2); b) midline shift was classified as 0-5 mm (=0) or >5 mm (=1); c) EDH was scored as present (=0) or absent (=1); and d) SAH#IVH was scored as absent (=0) or present (=1). One point was added to each summed Rotterdam score to achieve numerical consistency with the six-point Marshall score (2, 5).
A representative case showing how to calculate both scoring systems in TBI patient is shown in Fig. 3 on page 9.

**Analysis and Statistics:**

First, descriptive analyses were conducted to determine the prevalence of the maxillofacial fractures in patients with head trauma.

Next, the relationship between the presence of the maxillofacial fractures and the severity (Marshall and Rotterdam CT scores) of intracranial lesions was evaluated using Mann-Whitney U test. The relationship between the severity of the maxillofacial fracture (maxillofacial score) and the severity of intracranial lesions (Marshall and Rotterdam CT scores) was evaluated using Spearman correlation.

Finally, multiple logistic regressions were used to examine: a) the relationship between the five intracranial lesions and the presence of maxillofacial fracture anywhere in the maxillofacial region, and b) the relationship between the five intracranial lesions and the presence of fracture at each of the following three locations: periorbital, middle face or mandible.
Fig. 1: The periorbital zone was defined as region comprised between the roof and the floor of the orbit. Temporal bone was considered as skull base, therefore, excluded in this evaluation. The midface was defined as region bellow the orbital floor excluding the mandible which as considered as a different zone.

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Table 1: It shows how initial CT findings are differently grouped in the Marshall and in the Rotterdam CT scores. SAH/IVH: subarachnoid hemorrhage and/or intraventricular hemorrhage; EDH: epidural hematoma

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Fig. 2: The binary tree displaying the algorithm for calculation of the Marshall CT score.

### Rotterdam CT scoring system

<table>
<thead>
<tr>
<th>Predictor value</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basal cisterns</strong></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0</td>
</tr>
<tr>
<td>Compressed</td>
<td>1</td>
</tr>
<tr>
<td>Absent</td>
<td>2</td>
</tr>
<tr>
<td><strong>Midline shift</strong></td>
<td></td>
</tr>
<tr>
<td>No shift or shift ≤5mm</td>
<td>0</td>
</tr>
<tr>
<td>Shift &gt;5mm</td>
<td>1</td>
</tr>
<tr>
<td><strong>Epidural mass lesion</strong></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>1</td>
</tr>
<tr>
<td><strong>Intraventricular blood or subarachnoid hemorrhage</strong></td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td>0</td>
</tr>
<tr>
<td>Present</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sum score</strong></td>
<td>+1</td>
</tr>
</tbody>
</table>

**Table 2**

A representative case:
Calculation of Marshall and Rotterdam scores

- 88-Year-Old Female
- Fall in the restroom
- Glasgow coma scale = 4 out of 15 at admission
- CT: 3h after onset
- Subdural hematoma was surgically drainage
- She died later

Fig. 3: On the initial CT, the patient showed bilateral subdural hematoma (SDH), which is larger at the right side, leading to a leftward midline shift (of 17 mm) and compression of basal cisterns. The total volume of the SDH (right+left) was 35 ml. Acute subarachnoid hemorrhages (SAH) were also seen noted. According to the Marshall scoring system; because the total volume of the hemorrhagic mass (here represented by the bilateral SDH) was > 25 ml, the next step was to find out whether or not surgery was performed. As this patient underwent drainage (=surgery) of the right SDH, the patient was finally scored 5. According to the Rotterdam scoring system, the patient showed a compression of the basal cistern (=1), midline shift >5 mm (=1), absence of epidural hematoma (=1) and presence of SAH (=1). The patient got 4 points + 1 (that should be added to sum score from items), resulted to the overall score of 5. Thus, this patient was scored: Marshall=5 and Rotterdam=5.

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Results

**Prevalence of maxillofacial fractures**

Of the 1305 patients included in this study, 817 (62.6%) showed no pathological finding on head CT. Whereas 488 patients (37.4%) showed either a maxillofacial fracture or intracranial lesions as follows:

- 117 patients (24% of the 488 positive cases) showed a combination of maxillofacial fracture and intracranial lesion,
- 284 patients (58.2%) showed maxillofacial fractures without any intracranial lesions.
- The remaining 87 patients (17.8%) showed intracranial lesion without maxillofacial fracture.

**Relationship between the presence and the severity of maxillofacial fractures and the severity of intracranial lesions (Marshall and Rotterdam CT scores)**

More maxillofacial fractures were detected in higher Rotterdam and Marshall scores (Mann Whitney; P<0.0001 in both) (Fig. 4 on page 12).

Maxillofacial score showed significant positive correlation to both intracranial scores: Marshall (Spearman correlation: $\rho=0.29; p<0.0001$) and Rotterdam ($\rho=0.24; p<0.0001$).

**Relationship between maxillofacial fracture and the five intracranial lesions**

All results of multiple logistic regression analysis are shown in the Table 3 on page 12.

Of the five intracranial lesions, the presence of maxillofacial fracture anywhere in the maxillofacial regions was significantly associated with only SAH/IVH (P<0.001, multivariate analyses).

Likewise, the presence of maxillofacial fracture at periorbital, midface or mandibular regions was significantly associated with only the SAH/IVH (P<0.001, multivariate analyses), as well.
**Result**

*Relationship between maxillofacial fracture and Marshall or Rotterdam CT scores*

**Fig. 4:** More maxillofacial fractures are seen in higher Marshall and Rotterdam CT scores. In both Marshall and Rotterdam score, the upper bar, the lower bar, and the median of the box plots of patients without maxillofacial fracture, are confounded in a horizontal line, which is significantly lower than the median of the patients with maxillofacial fracture (P<0.0001). The mean diamonds clearly show that the mean Marshall or Rotterdam scores of patient with maxillofacial facture are significantly higher than that of patients without maxillofacial fracture (P<0.0001).

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### Results:

**Relationship between maxillofacial fractures and intracranial lesions by multiple logistic regression**

<table>
<thead>
<tr>
<th>Location of the Maxillofacial Fractures</th>
<th>Anywhere in the maxillofacial regions</th>
<th>Periorbital</th>
<th>Midface</th>
<th>Mandible</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTRACRANIAL LESIONS</strong></td>
<td>Adjusted OR</td>
<td>$P$ value</td>
<td>Adjusted OR</td>
<td>$P$ value</td>
</tr>
<tr>
<td>Status of basal cistern:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Normal</td>
<td>3</td>
<td>0.26</td>
<td>1</td>
<td>0.21</td>
</tr>
<tr>
<td>• Compressed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Absent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of midline shift:</td>
<td>2</td>
<td>0.15</td>
<td>1</td>
<td>0.99</td>
</tr>
<tr>
<td>Presence of SAH/IVH:</td>
<td>5</td>
<td>&lt;0.0001*</td>
<td>6</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Presence of EDH:</td>
<td>2</td>
<td>0.06</td>
<td>2</td>
<td>0.14</td>
</tr>
<tr>
<td>Hemorrhagic mass:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Absent</td>
<td>1</td>
<td>0.62</td>
<td>3</td>
<td>0.17</td>
</tr>
<tr>
<td>• &lt;25 ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• &gt;25 ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3:** OR: Odds ratio; SAH/IVH: subarachnoid hemorrhage and/or intraventricular hemorrhage; EDH: epidural hematoma; * statistically significant

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Conclusion

Discussion

Our data show that maxillofacial fractures constitute a common finding in patients with head trauma. Indeed, about one fourth of patients with positive head CT finding show association of maxillofacial fracture and intracranial lesions. Our additional finding also showed that when Marshall and Rotterdam score increased, the maxillofacial score also increased. This means that in severe head trauma both the maxillofacial and the intracranial regions are affected.

More interestingly, we have documented that of the 5 intracranial lesions assessed in this study, only SAH/IVH is significantly associated with the maxillofacial fractures regardless of their location (periorbital, middle face or mandible). To the best of our knowledge, this is the first large scale study to demonstrated this association.

In our precedent study (3), we have reported that the presence of IVH on initial CT predicts the presence of diffuse axonal injury (DAI) on the subsequent magnetic resonance imaging (MRI). This association was attributed to the assumption that both the IVH (and may be some type of SAH) and DAI are produced by the rotational acceleration ("shearing strain") which is one of the two main mechanisms of traumatic brain injuries; another mechanism being the "direct impact" that is thought to produced traumatic hemorrhagic mass lesions.

Based on the proven relationship between IVH on the initial CT and DAI detected on the subsequent MRI (3), we could speculate that the association documented in this study between maxillofacial fractures and SAH/IVH may indicate possible relationship between some maxillofacial fractures on initial CT and DAI detected on MRI. Some knockout punches that are observed in boxers after receiving a blow at their mandible could support our assumption. Indeed, a blow on the face may lead to rotational acceleration of the brain, which, if violent, could produce DAI in the brain and lead to an immediate loss of conscience (K.O of the boxer) (Fig. 5 on page 16)(6). A dedicated study to determine specific maxillofacial fractures that are associated with DAI should be conducted to allow proper selection of patients who should undergo MRI study for screening of DAI after maxillofacial trauma.

Conclusion
Our study showed that in severe head trauma, both the face and the brain are affected. More interestingly, maxillofacial fractures are associated with SAH/IVH which has recently been reported to predict diffuse axonal injury on MRI.
**Fig. 5:** Possible relationship between maxillofacial fracture and diffuse axonal injury (DAI). (A) After receiving a blow to the maxillofacial region, the brain may undergo a rotation acceleration (=shearing strain) (yellow curve arrow, A), which could lead to IVH/SAH (blue arrow, B) and DAI (black arrows, B). In support to our assumption, we showed a case of a 19 year old woman who was hit by a car while walking. On Initial CT, multiple right midface fractures (red arrows, C) were noted. Acute intracranial SAH (green arrow, D) was the only lesion that was seen in the brain parenchyma. On MRI, spotty hyperintensities (pink arrows, E) are seen on DWI at the left frontal lobe and at the genu of the corpus callosum, showing DAI.

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