Is supratentorial pressure difference clinically relevant? Analysis of 55 consecutive cases by bilateral intracranial pressure monitoring

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Objective: The purpose of this study is to explore the possibilities of an early warning system by measuring intracranial pressure differences in order to prevent secondary insults to the injured brain.

Methods: Fifty-five cases with a Glasgow coma scale (GCS) score 8 or below who presented with intracranial hypertension due to various intracranial pathologies underwent bilateral intraparenchymatous intracranial pressure (ICP) monitorization in an attempt to find out the existence of interhemispheric pressure differences. ICP values were recorded every 30 minutes during the first 24 hour interval. Patients were stratified into two groups as diffuse and focal according to the magnitude of their pathologies. Focal cases were also grouped according to lesion size and/or midline shift.

Results: ICP differences that necessitated changes in the treatment were found at different time intervals in patients with focal lesions, but these did not reach statistical significance within the whole group (p > 0.05). There were significant percentage differences between focal I and II groups in correlation with lesion side and non-lesion side within the first 4.5 hours (p < 0.05). There was a significant difference within the first 3 hours between diffuse and focal II groups (p < 0.05).

Discussion: In patients with focal lesions, although more pronounced in focal II group, apparent pressure differences between two hemispheres within the first hours of admission were found. These pressure differences were related to the volume of the intracranial pathology. ICP monitorization from the lesion side is reasonable as an early forewarning procedure and this might prevent the development of secondary insults by providing the exact ICP values of the patients. [Neurol Res 2008; 000: 000–000]

Keywords: Diffuse lesion; focal lesion; head trauma; intracranial pressure monitorization; intracranial pressure gradient

INTRODUCTION

Intracranial pressure (ICP) is a major predictor of mortality and morbidity in patients with traumatic brain injury, subarachnoid hemorrhage, intracerebral hemorrhage and stroke1–4. Accordingly, significant effort in neurointensive care is directed at preventing and treating intracranial hypertension and maintaining sufficient cerebral perfusion pressure (CPP) in advance. The objective in the management protocol of cases with a Glasgow coma scale (GCS) score 8 or below is to provide a cerebral perfusion pressure within required limits (70 mmHg or above) and to avoid ischemic trauma. This can be successfully achieved only by knowing the ICP and mean arterial pressure measurements in an early interval of secondary insult. Intraparenchymatous ICP monitorization is one of the most commonly used methods of ICP measurement among others such as intraventricular, subdural and epidural monitorization5,6. The validity of unilateral intraparenchymatous ICP monitorization as a proper measure of global ICP, depends on the concept that intracranial compartment acts as a single chamber with equally distributed pressures. However, the balance of ICP in different compartments of the brain is still a matter of debate, and distinct clinical and experimental works have investigated whether any interhemispheric pressure difference exists that may effect the target and timing of management7–9. These works have conflicting results about presence and/or significance of interhemispheric pressure gradients7–10. The discrepancies among these studies have been attributed to the use of different types of methodologies and unreliable fluid-coupled transducers9. In this report, by employing bilateral concurrent fiberoptic intraparenchymatous ICP monitorization technique in patients admitted to the intensive care unit due to various neurosurgical pathologies with a GCS score 8 or below, we intended
to find out the existence of any pressure difference between cerebral hemispheres and interhemispheric pressure changes with time that might have an effect on the management of the ICP and to establish early warning system using these findings in a relatively large number of patients with various intracranial pathologies.

MATERIALS AND METHODS
This study is based on 55 consecutive patients with various intracranial pathologies who were admitted to the neurosurgical intensive care unit of the Uludag University Hospital between October 2002 and October 2003. Inclusion criteria for the study were age between 18 and 65 years old and a GCS score of 8 or below. Our patient series did not include gunshot wounds of the head, or those were apneic on admission to the emergency room and fulfilled the criteria for brain death. Patients with dural or bone defects were excluded from the study. Study protocol was approved by the Ethic Committee of Uludag University and informed consent was obtained from the patients’ next of kin.

ICP monitorization
ICP monitorization and other catheterization (radial artery, CVP and/or Jugular catheter, etc.) procedures were performed under local anesthesia. None of the patients had their hair cut, but it was scrubbed gently for 8–10 minutes using 4% chlorhexidine diluted 50:50 with water. After drying with a sterile towel, the area was washed with 10% povidon iodine solution. The transducers were introduced at a point 10 cm posterior to the glabella and 3 cm lateral to the midline on the left and right bilaterally. The transducers were dressed on a daily basis and examined for the local wound infection.

ICP values were recorded every 30 minutes during the first 24 hours. Then the transducer contralateral to the lesion was removed and monitorization continued with the transducer ipsilateral to the lesion. A routine CT scan was performed in all patients at the end of the first 24 hours. There were no complications related to ICP monitorization. The dimension of the focal lesions was calculated according to the modified ellipsoid volume \((A \times B \times C \times 0.5)\) where \(A, B\) and \(C\) are the diameters of the clot on CT in each of the three measurements. Midline shift was measured by baseline and control CTs. Patients were classified by the worst CT (the largest midline shift or/and biggest focal lesion). Patients were divided into four groups according to their CT findings (midline shift, lesion size and position of the mesencephalic cisterns) (Table 1).  

### Analysis of ICP
Fifty ICP values that were recorded within 24 hours were evaluated and average ICP values of each hemisphere were calculated for each patient. ICP values of each patient were examined for brief period temporary pressure gradients.

### Statistical analysis
Regression analysis of each case and each time period and linear relationship between ICP values were carried out. In regression analysis, the independent variable was the lesion side in cases with focal lesions, but it was left hemisphere in cases with diffuse lesions. Percent variations in time intervals were calculated. While calculating percent variations of both sides according to each other, statistical comparisons between groups were made using Mann–Whitney U test. Wilcoxon test was used while comparing right and left sides of cases within each group. \(r^2\) was calculated to find out how much the model explained the event in regression models which were found to be statistically significant. \(r^2 > 0.05\) were the accepted significance level in statistical comparisons; \(p \leq 0.05\) was considered statistically significant. SPSS version 11.0 was used for the statistical analysis.

### RESULTS
This study involves 55 patients: 29 (53%) were female and 26 (47%) were male. Their ages ranged from 8 to 82 (mean age: 45.3 ± 18) years old. Patient characteristics are shown in Table 2. Subarachnoid hemorrhage (SAH) (38.2%) and intracerebral hemorrhage (ICH) (36.4%) were the most commonly encountered pathologies. The average GCS score of patients was 6.

According to their CT scans, 31 (56.3%) of the patients were in the diffuse group, while 24 (43.6%) were in the focal group I [14 (25.4%) in the focal group I and ten (18.2%) in the focal group II] (Table 3).

### Analysis of ICP
Fifty ICP values that were recorded within 24 hours were evaluated. Average ICP values of each hemisphere were calculated for each patient. ICP values of individuals were examined for short period temporary pressure gradients.

### Classification of ICP forms
We evaluated ICP values in four groups according to Sahuquillo et al.  

#### ICP group 1
Pressure differences between hemispheres were 3 mmHg or below and ICP wave form were in similarity with or without treatment (Figure 1A).

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**Table 1**: Classification of patients according to CT findings

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Diffuse</td>
<td>Hemispheric lesions sized below 25 ml and midline shift 5 mm or below, bone fragment or foreign matter in brain parenchyma</td>
</tr>
<tr>
<td>Focal I</td>
<td>Lesions of one hemisphere above 25 ml and midline shift 5 mm or below, compression of basal cisterns</td>
</tr>
<tr>
<td>Focal II</td>
<td>Independent from the volume of the lesions of the hemisphere, midline shift is above 5 mm and/or in patients operated for any lesions</td>
</tr>
</tbody>
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ICP group 2

Average ICP difference between hemispheres was 3 mmHg or above (Figure 1B).

ICP group 3

There are completely different ICP values and forms. Patients who had pressure differences in more than 25% of the recorded total ICP values were analysed in this group (Figure 1C).

Lesion type and ICP differences

When classified according to ICP values previously stated, 21 (38.1%) of the patients were in the ICP group I (Table 3). While 16 (76.1%) of these had diffuse lesion, five (23.8%) had focal lesion (two in focal group I and three in focal group II). Correlation coefficient was 0.85 ± 0.11 for these cases. Surgery was performed on four of the cases in this group due to subdural hematoma in two cases and intracerebral hematoma in two cases.

There were 16 (29.0%) cases in the ICP group 2; while 11 (68.7%) of them had focal lesions (six in focal I and five in focal II), five (31.5%) cases had diffuse lesions. Correlation coefficients of ICPs between both hemispheres were 0.64 ± 0.23. Surgery was performed before monorization on seven (43.7%) of the cases in this group due to various reasons (epidural hematoma in three cases and ICH in four cases) (Figure 2).

There were 18 (32.7%) cases in the ICP group 3; eight (44.4%) had focal lesion (six in focal I and two in focal II), and ten (55.5%) had diffuse lesion. Correlation coefficients were 0.45 ± 0.47. Surgery was performed on two of the patients in this group before monitorization due to various indications (one case of ICH and one case of subdural hematoma) (Figure 3).

When pressure differences were analysed between lesion and non-lesion sides, positive differences at the various time intervals on the lesion side needing change of the treatment modality were noted in a total of 23 (41.8%) cases. Of these cases, five were in ICP group I, six in ICP group II and 12 were in ICP group III (Figure 4).

When cranial CT lesions were taken into account, Wilcoxon signed rank test showed no significant differences between ICP values of two hemispheres in the diffuse group and between lesion and non-lesion sides in the focal group (p > 0.05). In ICP values determined by Mann–Whitney U test according to percent differences, no statistical significance was found

<table>
<thead>
<tr>
<th>Etiology/pathology</th>
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<tr>
<td>Road accident</td>
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<tr>
<td>Epidural hematoma</td>
<td>2</td>
</tr>
<tr>
<td>t-SAH</td>
<td>10</td>
</tr>
<tr>
<td>ICH</td>
<td>2</td>
</tr>
<tr>
<td>Contusion</td>
<td>3</td>
</tr>
<tr>
<td>Subdural hematoma + contusion</td>
<td>1</td>
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<tr>
<td>High falls</td>
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<tr>
<td>Epidural hematoma</td>
<td>2</td>
</tr>
<tr>
<td>Contusion</td>
<td>1</td>
</tr>
<tr>
<td>SAH</td>
<td>10</td>
</tr>
<tr>
<td>ICH</td>
<td>18</td>
</tr>
<tr>
<td>Gliomatosis cerebri</td>
<td>1</td>
</tr>
<tr>
<td>Infarction</td>
<td>1</td>
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<tr>
<td>Physical assault</td>
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</tr>
<tr>
<td>t-SAH</td>
<td>1</td>
</tr>
<tr>
<td>Contusion</td>
<td>2</td>
</tr>
<tr>
<td>Venous sinus thrombosis</td>
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</tbody>
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t-SAH: traumatic subarachnoid hemorrhage, SAH: subarachnoid hemorrhage, ICH: intracerebral hemorrhage.

Table 3: Distribution of the ICP groups according to CT findings

<table>
<thead>
<tr>
<th>ICP groups</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse</td>
<td>16</td>
<td>5</td>
<td>10</td>
<td>31</td>
</tr>
<tr>
<td>Focal I</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Focal II</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>16</td>
<td>18</td>
<td>55</td>
</tr>
</tbody>
</table>
between hemispheres within the same group \((p>0.05)\). Some patients with focal lesions had some ICP differences during different time intervals that urged change in the treatment modality, but within group values did not reach statistical significance \((p>0.05)\). During the first 4 and a half hours between focal I and II groups and during first 3 hours between diffuse and focal II groups, statistical significances were found in percentile differences, values being higher in the right hemisphere \((p<0.05)\).

**DISCUSSION**

The purpose of the management of patients in the intensive care unit with suspected mass effect due to trauma or cerebrovascular accident is to prevent primarily insulted brain from secondary insults.
Increased ICP (above 20 mmHg) and low cerebral perfusion pressure (below 70 mmHg) are two important indicators for secondary insults affecting improvement in severe head trauma and ischemia cases. Normally, there is a minimal pressure difference between cerebral hemispheres. In case of brain shift or obstruction in the subarachnoid space, pressure equalization between compartments may be lost due to rapid loss of brain compliance. Pressure differences between supra and infratentorial compartments and between posterior fossa and spinal subarachnoid space have been shown in different animal models and in a few works dealing with supratentorial ICP differences from a clinical point of view. Although pressure differences in the same or between hemispheres have been shown in literature, there is still a debate on the presence of supratentorial interhemispheric pressure differences.

As early as 1885, von Bergmann concluded that ICP was not always distributed equally in all directions of the brain. Crockard et al. showed a constant pressure difference between anterior and posterior parts of obstructed lateral ventricle by a thalamic mass lesion. In another report, Broaddus et al. used frontal and parietal subarachnoid bolts located to the same hemisphere and showed in excess of 10 mmHg interhemispheric differences in 47% of the cases with masses. In 1992, Gambardella et al. showed transient ICP gradients in patients with unilateral mass lesions and midline shift. In 1998, Mindermann et al. observed transient interhemispheric pressure gradients of 6–10 mmHg that normalized over a course of 6–7 hours in head trauma patients. These conflicting data have been attributed to different methodologies and unreliable fluid-coupled transducers.

Gambardella et al. definitely found significant relationship between two hemispheres in six cases that had bilateral simultaneous ICP monitoring. There were transient ICP differences lasting less than 2 hours and being in the range of 10–20 mmHg in four of the cases. Transient pressure differences were particularly noted to appear in cases that had a sudden increase in brain volume, especially ipsilateral to the mass lesion. In accordance with this study, Yoshihara et al. presented the possibility of transient differences in focal lesions which in most cases tended to disappear in time. In these cases, ICP in intracranial spaces was shown to be distributed unevenly during a variable time interval, so the intracranial space behaved as two different compartments. In our relevant analysis, high pressure values of focal II group in the lesion side were considerably higher than the values in the diffuse and focal I groups. These pressure differences later affected the opposite side, increasing the pressure, so that pressures of the both sides became eventually equal. This could be seen in a few patients with lesions of greater volumes. In our study, ICP monitoring of patients with a GCS score 8 or below supports the idea that pressure differences between two hemispheres occur during the first 3–4 hours. In an experiment with monkeys, D’Ambrosio et al. reported significant interhemispheric pressure differences only if the lesion eventually reached to a size that was 20% more than its original size. Pressure values being higher ipsilateral to lesion site in the focal group II were significantly different than those of the diffuse and focal group I patients. These pressure differences then started to have an impact on the contralateral hemisphere which resulted in equal pressures in both of the hemispheres.

As stated in literature, intracranial supratentorial compartment behaves as a single space in diffuse lesions. ICP values in both hemispheres were similar in our cases with diffuse lesions. ICP increases in both hemispheres were in relation with each other. By considering rapid growth potential of small focal lesions, we recommended monitoring of cases with diffuse lesions with small focal lesions ipsilateral to lesion site. Determination of pressure changes that will produce ICP differences during the first hour of lesion development is a relevant issue in preventing secondary insults. In some of our cases, ICP changes that vigorously urged treatment modality changes were determined. For prompt intervention of cases with rapid increases in the mass size, monitoring ipsilateral to lesion will be life-saving. However, there is still a
technical challenge in obtaining data for bilateral monitorization.

CONCLUSION
Patients with a GCS score of 8 or below requiring intensive care should be monitored by ICP, except for a few patients with contraindications. This will enables us to make a strategic determination of the treatment modality using the information regarding the real ICP values. Since the goal of neurointensive care treatment is to prevent secondary insults, identifying ICP values for all regions of cerebral hemispheres will contribute to decrease mortality and morbidity in an early period. In our analysis, intracranial interhemispheric pressure differences were shown to occur during the first 3–4.5 hours, particularly in the focal II group, and ICP monitorization from the lesion site will provide an early determination of high pressure values, suggesting pressure differences between the two hemispheres, and this should be helpful in the appropriate management of the patient.

ACKNOWLEDGEMENT
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REFERENCES
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