Prognostic value of early computerized tomography scanning following craniotomy for traumatic hematomas

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Object. Patients with head injuries traditionally were categorized on the basis of whether their lesions appeared to be diffuse, focal, or mass lesions on admission computerized tomography (CT) scanning. In the classification of Marshall, et al., the presence of a hematoma (evacuated or not evacuated) is more significant than any diffuse injury (DI). The CT scan appearance after evacuation of a mass lesion has not been analyzed previously in relation to outcome. The authors have investigated the importance of: 1) neurological assessment at hospital admission; 2) the status of the basal cisterns and associated intracranial lesions on the admission CT scan; and 3) the degree of DI on the early CT scan obtained after craniotomy to identify patients at risk for development of raised intracranial pressure (ICP) and lowered cerebral perfusion pressure (CPP) and to discover the influence of the postoperative CT appearance of the lesion on patient outcome.

Methods. The authors prospectively studied 82 patients with isolated, severe closed head injury (Glasgow Coma Scale [GCS] score ≤ 8), all of whom had intracranial hematoma. Both ICP and CPP were continuously monitored, and a CT scan was obtained within 2 to 12 hours after craniotomy. The CT images were categorized according to the classification of Marshall, et al.

The mortality rate during the hospital stay was 37%, and 50% of the patients achieved a favorable outcome. Compression of the basal cistern on the admission (preoperative) CT scan was associated with raised ICP and a CPP of less than 70 mm Hg but not with any other features or with poor patient outcome. In 53 patients the postoperative CT scan revealed DIs III or IV and 29 patients had DIs I or II. The percentages of time during the hospital stay in which ICP was higher than 20 mm Hg and CPP was lower than 70 mm Hg as well as unfavorable outcome were higher in the group of patients in whom DI III or IV was present (p < 0.001). Raised ICP, CPP lower than 70 mm Hg, DI III or IV, and unfavorable outcome were more frequently observed in patients who presented with a motor (m)GCS score of 3 or less, bilateral unreactive pupils, associated intracranial injuries, and hypotension (p < 0.001). When logistic regression analysis was performed, an mGCS score of 3 or less (p = 0.0013, odds ratio [OR] 10.8), bilateral unreactive pupils (p = 0.0047, OR 31.8), and DI III or IV observed on CT scanning after surgery (p = 0.015, OR 8.9) were independently associated with poor outcome.

Conclusions. Features on CT scans obtained shortly after craniotomy constitute an independent predictor of outcome in patients with traumatic hematoma. Patients in whom DI III or IV appears on postoperative CT scanning, who often present with an mGCS score of 3 or less and nonreactive pupils, are at high risk for the development of raised ICP and lowered CPP.

KEY WORDS • head injury • intracranial hematoma • computerized tomography scanning • intracranial pressure • cerebral perfusion pressure • outcome

EUROsurgeons and others interested in treating head-injured patients have traditionally categorized head injury on the basis of differentiating diffuse lesions from focal or mass lesions. These categorizations have significant limitations for prognosis because they have been based on early admission computerized tomography (CT) scan features. It is generally recognized that patients with diffuse injury (DI) have a lower mortality rate than patients with mass lesions. However, the use of this general classification might mask groups of patients with both DIs and focal lesions who are at risk from raised intracranial pressure (ICP) and who, in fact, may face a higher risk of mortality. Therefore, patients who exhibit DI after craniotomy for intracranial hematomas could experience raised levels of ICP and face higher risks of morbidity and mortality. It is possible that CT scanning performed immediately or within 12 hours after surgery might provide more adequate identification of the extent of the DI and the need for continuous monitoring of ICP and aggressive treatment.

Although the impacts of different degrees and locations of evacuated mass lesions have been extensively reported, in the present study, we investigated the importance of the following: 1) neurological assessment on admission to the hospital; 2) status of the basal cisterns and associated intracranial lesions on the admission CT scan; and 3) the degree of DI on the CT scan obtained shortly after craniotomy to identify patients with a low or high risk for development of raised ICP.

Clinical Material and Methods

Patient Population and Case Management

We prospectively studied 82 patients with severe head
The best motor GCS (mGCS) score and pupil reactions after resuscitation were obtained at the scene or immediately after admission to our hospital. The patients were assigned to one of two groups, depending on whether their best mGCS score was greater than 3 or 3 or less. With respect to the pupillary response, the patients were classified as having no, one, or two reactive pupils. Prehospital arterial hypotension was defined as one or more recordings of systolic blood pressure at lower than 90 mm Hg.

### Computerized Tomography Scanning at Admission and Postsurgery

All patients at admission were classified as having focal lesions requiring evacuation (evacuated mass lesion on the classification of Marshall, et al.\(^\text{19}\)). In reviewing the CT scan obtained at admission, we also evaluated the associated intracranial injuries (presence of intraventricular hemorrhage, intracerebral hematoma, cerebral contusions with densities lower than 25 cm\(^3\), subarachnoid hemorrhage [SAH], and effaced basal cisterns). Another CT scan was obtained in all patients within 2 to 12 hours after surgery and this was categorized according to the classification of Marshall, et al.: DI I, normal CT scan with no visible pathological entity for a patient of that specific age and preinjury health status; DI II, cisterns present with a 0- to 5-mm midline shift and/or lesion densities present (no high- or mixed-density lesion > 25 cm\(^3\); may include bone fragments and foreign bodies); DI III (swelling), cisterns compressed or absent with a 0- to 5-mm midline shift and no high- or mixed-density lesion larger than 25 cm\(^3\); and DI IV (shift), midline shift greater than 5 mm and no high- or mixed-density lesion larger than 25 cm\(^3\). The patients were divided into one of two groups according to the findings on the postoperative CT scan. The first group included patients with DIs I and II and the second group included those with DIs III and IV. Postoperatively, there were no patients in this selected series with residual or recurrent mass lesions (> 25 cm\(^3\)).

### Monitoring of ICP and CPP

We studied the percentage of time that ICP was higher than 20 mm Hg and CPP lower than 70 mm Hg by applying this formula: 100 × the number of hours with ICP greater than 20 mm Hg or CPP less than 70 mm Hg ÷ total hours of ICP and CPP monitoring gathered from the nursing chart. We only included in this study patients in whom ICP was monitored for at least 24 hours, and to apply this formula, we only included the numbers of hours, up until a 24-hour period had elapsed, during which ICP was always less than 20 mm Hg. For this reason, it is reasonable to express the duration of insult as a percentage of the total monitoring period.

### Patient Outcome

Patient outcome was evaluated using the five-point Glasgow Outcome Scale\(^\text{15}\) (GOS) after 6 months of follow-up review; for statistical purposes, we limited outcome to two groups—favorable and unfavorable. Patients in the upper two GOS outcome groups (good recovery and moderate disability) were considered to have a favorable outcome. Patients in the lower three outcome groups (severe disability, vegetative state, or death) were considered to have a poor outcome.

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### Table 1

**Characteristics and outcome in 82 patients who underwent craniotomy for traumatic hematoma**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Favorable Outcome</th>
<th>Unfavorable Outcome</th>
<th>OR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal cisterns present</td>
<td>30 (57.7)</td>
<td>22 (42.3)</td>
<td>2.35 (0.93–5.9)</td>
<td>NS</td>
</tr>
<tr>
<td>Compressed</td>
<td>11 (36.7)</td>
<td>19 (63.3)</td>
<td>0.42 (0.1–1.0)</td>
<td>NS</td>
</tr>
<tr>
<td>Postop CT finding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI I or II</td>
<td>26 (89.6)</td>
<td>3 (10.3)</td>
<td>0.04 (0.01–0.1)</td>
<td>0.001</td>
</tr>
<tr>
<td>DI III or IV</td>
<td>15 (28.3)</td>
<td>38 (71.7)</td>
<td>21.95 (5.7–83.5)</td>
<td>0.001</td>
</tr>
<tr>
<td>Systolic blood pressure ≤ 90 mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associated intracranial lesions</td>
<td>15 (31.2)</td>
<td>33 (68.8)</td>
<td>7.15 (2.6–19.4)</td>
<td>0.001</td>
</tr>
<tr>
<td>Bilat reactive</td>
<td>32 (82)</td>
<td>7 (18)</td>
<td>0.57 (0.01–0.1)</td>
<td>0.001</td>
</tr>
<tr>
<td>Bilat unreactive</td>
<td>8 (42.1)</td>
<td>11 (57.9)</td>
<td>15 (0.5–4.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Unilat unreactive</td>
<td>1 (4.2)</td>
<td>23 (95.8)</td>
<td>51.1 (6.3–408.2)</td>
<td>0.001</td>
</tr>
<tr>
<td>MmGCS score ≤ 3</td>
<td>5 (13.5)</td>
<td>32 (86.5)</td>
<td>25.6 (7.7–84.3)</td>
<td>0.001</td>
</tr>
<tr>
<td>Mean patient age (yrs)</td>
<td>34.3 ± 14</td>
<td>38.7 ± 16.1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No. of patients</td>
<td>41</td>
<td>41</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* CI = confidence interval; NS = nonsignificant; OR = odds ratio; — = not applicable.

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The best motor GCS (mGCS) score and pupil reactions after resuscitation were obtained at the scene or immediately after admission to our hospital. The patients were assigned to one of two groups, depending on whether their best mGCS score was greater than 3 or 3 or less. With respect to the pupillary response, the patients were classified as having no, one, or two reactive pupils. Prehospital arterial hypotension was defined as one or more recordings of systolic blood pressure at lower than 90 mm Hg.
Early CT scanning after traumatic hematoma

**Statistical Analysis**

Discrete variables were compared using chi-square analysis or Fisher’s exact test. Continuous variables were compared using the Wilcoxon or Kruskal–Wallis test according to the number of categories of the variables. Differences at the 0.05 level were considered statistically significant. Logistic regression models were used to determine which variables would predict outcome (either favorable or unfavorable) or the degree of DI after surgery according to the Marshall, et al., classification. Statistical analysis was performed using a commercially available computer software package (SPSS, Inc., Chicago, IL).

**Results**

**General Results**

We followed 82 patients with isolated and severe closed head injury who were admitted to the ICU following surgical evacuation of an intracranial hematoma. The mean age of the patients was 36.3 ± 26.5 years (range 16–76 years). There were 76 males and six females. The causes of injury included: falls in 32 cases (39%); motorcycle accidents in 22 (26.8%); automobile–pedestrian collisions in 18 (22%); motor vehicle crashes in eight (9.8%); and assaults in two cases (2.4%).

The median GCS score at admission and after resuscitation was 6 (range 3–8). Forty percent of the patients had a GCS score of 5 or less and 45% had an mGCS score of 3 or less.

Twenty-four patients (29%) had bilateral unreactive pupils on admission, 19 (23%) had unilateral reactive pupils, and 39 (48%) had bilateral reactive pupils. There were 27 patients (33%) with prehospital arterial hypotension.

Thirty patients (37%) died during their hospital stay. All hospital survivors (52 patients) participated in follow-up review. Six months after hospital discharge 41 survivors (50% of total) had favorable outcomes; 11 had unfavorable outcomes including four deaths.

**Admission Characteristics**

The results of the neurological assessment and the CT scans obtained at admission and early postsurgery from both favorable and unfavorable groups were compared to see if any findings were associated with a poor prognosis. Unfavorable outcome (severe disability, vegetative state, or death) was more likely to occur in patients who had an mGCS score of 3 or less and hypotension, nonreactive pupils, associated intracranial injuries, and postsurgery DI II or IV. The status of the basal cisterns on the CT scan obtained at admission did not influence outcome. Survivors with favorable outcomes more frequently had bilateral reactive pupils and a postsurgical CT appearance of DI I or II (Table 1).

Of the 82 patients studied, 42 (51.2%) underwent surgical evacuation of a subdural hematoma, 23 (28%) an intracerebral hematoma, and 17 (20.7%) an epidural hematoma. Most cases of unfavorable outcome (69%) and postsurgery DI III or IV occurred in patients with subdural hematoma; however, this was not a statistically significant difference compared with patients with intracerebral or epidural hematomas. The lack of significance probably reflects the small numbers in each group. Effaced basal cisterns were more frequently found in patients with subdural hematoma (p < 0.05; Table 2).

**Monitoring of ICP and CPP and Patient Outcome**

In addition to intracranial hematoma, effaced basal cisterns were observed on admission CT scans in 30 patients. The median percentages of hours during which ICP was higher than 20 mm Hg and CPP was lower than 70 mm Hg were 31 and 11, respectively, in this group. Of the remaining 52 patients with normal basal cisterns, the median percentages of time that ICP was higher than 20 mm Hg and CPP was lower than 70 mm Hg were 21% and 7%, respectively. The differences in the percentages of time during which ICP was elevated and CPP lowered to these levels were statistically significant (p < 0.01); however, both groups of patients had similar morbidity and mortality rates (Tables 1 and 3).

In 53 patients DI III or IV was observed on the postoperative CT scan. In the same patients the median percentages of hours during which ICP was higher than 20 mm Hg and CPP was lower than 70 mm Hg were 39.8 and 17.8, respectively. Of these 53 patients, 38 (72%) had a poor outcome at 6-month follow up (32 patients deceased and six with severe disability). In the remaining 29 patients there was CT evidence of DI I or II, and only 10 patients (34%) presented with an ICP higher than 20 mm Hg and eight patients (26.7%) with a CPP lower than 70 mm Hg during the period of monitoring. Three patients in the latter group were included in the group having unfavorable outcomes. The differences in percentages of time during which ICP was elevated and CPP lowered and the presence of unfavorable outcome were statistically significant when patients with DI III or IV were compared with patients with CI I or II (p < 0.001; Tables 1 and 3).

When we analyzed the effects of mGCS score, pupillary reactivity, presence of associated intracranial injuries, and presence of hypotension, we found that elevated ICP (> 20 mm Hg), lowered CPP (< 70 mm Hg), and unfavorable outcome more frequently occurred in those patients who presented with an mGCS score of 3 or less, bilateral unreactive pupils, associated intracranial injuries, and hypotension; this difference was statistically significant (p < 0.001; Tables 1 and 3).

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**TABLE 2**

* Type of intracranial mass findings on admission and postoperative CT scans, and outcome in 82 patients who underwent craniotomy

<table>
<thead>
<tr>
<th>Intracranial Mass</th>
<th>Admission CT Scan: Basal Cisterns</th>
<th>Postop CT Scan</th>
<th>No. W/ Poor Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Patients</td>
<td>Compressed</td>
<td>DI I or II</td>
</tr>
<tr>
<td>subdural</td>
<td>42</td>
<td>19</td>
<td>23*</td>
</tr>
<tr>
<td>intracerebral</td>
<td>23</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>epidural</td>
<td>17</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>total no. of patients</td>
<td>82</td>
<td>52</td>
<td>30</td>
</tr>
</tbody>
</table>

* p < 0.05.
In an effort to understand which factors were independent predictors of outcome (particularly in relation to postevacuation DI), logistic regression analysis of the independent outcome predictor along with patient age, GCS score, CT scan diagnosis, and pupillary reactivity. In our series, 33% of the patients were hypotensive during the prehospital period, and this variable influenced incidences of morbidity and mortality (OR 11.81; 95% CI 3.5–39.5; p < 0.001) and the appearance of DI III or IV (p = 0.015, OR 8.9) was independently associated with outcome. An mGCS score of 3 or less (p = 0.0016, OR 9.25) was the only independent factor associated with postoperative CT findings of DI III or IV. Bilateral reactive pupils on admission (p = 0.01, OR 0.21) were independently associated with DI I or II.

Discussion

In evaluating patients with head injury, we have studied those with intracranial mass lesions that required evacuation. Features studied included patient age, mGCS score, the presence of associated lesions of major significance (such as SAH and contusions), prehospital hypotension, pupillary reactivity, maximum ICP (≤ 20 mm Hg CPP > 70 mm Hg), and recently, episodes of jugular venous oxygen desaturation. In our study, an mGCS score of 3 or less, hypotension, associated intracranial lesions, and pupillary reactivity predicted not only outcome but the type of DI found on the postoperative CT scan. Also, these factors predicted that head-injured patients could have an ICP higher than 20 mm Hg and a CPP lower than 70 mm Hg.

Prehospital Hypotension

The prehospital phase is perhaps the most important in determining the ultimate outcome after clinical traumatic brain injury, and rapid intervention to prevent secondary brain damage is critical. Chesnut, et al., in a series of 717 patients, reported that hypotension occurred in 34% of comatose patients between the time of injury and resuscitation and that it was a statistically significant independent outcome predictor along with patient age, GCS score, CT scan diagnosis, and pupillary reactivity. In our series, 33% of the patients were hypotensive during the prehospital period, and this variable influenced incidences of morbidity and mortality (OR 11.81; 95% CI 3.5–39.5; p < 0.001) and the appearance of DI III or IV on the postoperative CT scan (OR 7.11 [95% CI 1.9–26.6]; p < 0.001). However, when all variables were evaluated using logistic regression, prehospital hypotension was not an independent outcome predictor. This could be related to the fact that our patients presented with isolated severe head injury population was performed. An mGCS score of 3 or less (p = 0.0013, OR 10.8), bilateral unreactive pupils (p = 0.0047, OR 31.8), and postoperative CT findings of DI III and IV (p = 0.015, OR 8.9) were independently associated with outcome. An mGCS score of 3 or less (p = 0.0016, OR 9.25) was the only independent factor associated with postoperative CT findings of DI III or IV. Bilateral reactive pupils on admission (p = 0.01, OR 0.21) were independently associated with DI I or II.

Features on CT Scanning

Tables 4 and 5 show the effects of the admission variables on the admission and postoperative CT scans. All variables (mGCS score ≤ 3, bilateral unreactive pupils, hypotension, and associated intracranial lesions) occurred more frequently in patients in whom postoperative CT scanning revealed DI III or IV than in patients in whom it was DI I or II (p < 0.001). By contrast, the finding of effaced basal cisterns on the admission CT scan was not associated with those variables.

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TABLE 3

Comparison between diffuse injury after craniotomy and variables at admission and the percentages of time during which patients had intracranial hypertension and low CPP

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ICP &gt;20 mm Hg</th>
<th>CPP &lt;70 mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PS0</td>
<td>p Value</td>
</tr>
<tr>
<td>mGCS score ≤ 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>48</td>
<td>0.001†</td>
</tr>
<tr>
<td>no</td>
<td>8.5</td>
<td>0</td>
</tr>
<tr>
<td>pupil(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bilat unreactive</td>
<td>65.5</td>
<td>0.001†</td>
</tr>
<tr>
<td>unilat unreactive</td>
<td>29</td>
<td>0.001†</td>
</tr>
<tr>
<td>bilat reactive</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>systolic BP ≤ 90 mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>50</td>
<td>0.001†</td>
</tr>
<tr>
<td>no</td>
<td>17</td>
<td>0.001†</td>
</tr>
<tr>
<td>associated intracranial lesions on postop CT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>33.5</td>
<td>0.001†</td>
</tr>
<tr>
<td>no</td>
<td>7.3</td>
<td>0</td>
</tr>
<tr>
<td>basal cisterns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>present</td>
<td>13.5</td>
<td>0.001†</td>
</tr>
<tr>
<td>compressed</td>
<td>35.4</td>
<td>0</td>
</tr>
<tr>
<td>postop CT evidence of DI II or IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>39.8</td>
<td>0.001†</td>
</tr>
<tr>
<td>no</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* BP = blood pressure; PS0 = median percentage.
† Wilcoxon test.
‡ Kruskal–Wallis test.

TABLE 4

Comparison of basal cistern status on admission CT scan and other admission variables

<table>
<thead>
<tr>
<th>Admission Variable</th>
<th>Basal Cisterns:</th>
<th>p OR (95% CI) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of patients</td>
<td>Present</td>
<td>Compressed</td>
</tr>
<tr>
<td>mGCS score ≤ 3</td>
<td>52</td>
<td>30</td>
</tr>
<tr>
<td>pupil(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unilat unreactive</td>
<td>10</td>
<td>47.4</td>
</tr>
<tr>
<td>bilat unreactive</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>bilat reactive</td>
<td>30</td>
<td>23.1</td>
</tr>
<tr>
<td>systolic BP &lt; 90 mm Hg</td>
<td>18</td>
<td>33.3</td>
</tr>
<tr>
<td>associated intracranial lesions</td>
<td>27</td>
<td>43.8</td>
</tr>
</tbody>
</table>
injury, and therefore, the appearance of hypotension could be due to direct brain damage. Nevertheless, it is difficult to quantify the extent and duration of hypotension in terms of magnitude and duration in the field, and for this reason, controlling for this critical factor is problematic. However, the influence of systemic brain insults, particularly hypotension, on outcome from severe head injury has been confirmed in prospective studies published by several authors.6,9,10,15

**Glasgow Coma Scale Score and Pupillary Reactivity**

The well-established prognostic value of the mGCS score17 observed on admission was supported by our data. Loss of reactivity of both pupils in a patient with traumatic intracranial hematoma is recognized as a most ominous sign, especially when it follows deterioration in consciousness and motor response. Sakas, et al.,27 reported that 25% of patients with fixed dilated pupils made a favorable recovery following craniotomy for traumatic hematoma. In our study, of the 24 patients who presented with unreactive pupils on admission, 17 (70%) had a subdural hematoma and three (12.5%) an intracerebral hematoma; all of these had a poor outcome. Only one of the four remaining patients with an epidural hematoma and bilateral fixed dilated pupils survived with a favorable outcome.

**Computerized Tomography Scanning at Admission**

Computerized tomography scanning is indispensable in the diagnostic and serial evaluation of patients suffering from severe head injuries and has been used as a tool for assessing outcome in such patients. Toutant, et al.,31 and Murphy, et al.,22 reported finding an association between compressed or absent basal cisterns and ICP exceeding 25 mm Hg; these authors confirmed the powerful relationship with patient outcome. Based on data obtained from the Traumatic Coma Data Bank, Marshall and colleagues19 reported that patients with DI I or II on admission had lower morbidity and mortality rates than those with DI III or IV. Effacement of the basal cisterns and midline shift were also signs of severity in patients with diffuse head injury. The CT scanning features noted in patients with intracranial hematoma at admission included size and location of the injury, midline shift, basal cisterns status, and presence of associated lesions. These features have been taken as indicators of the need for emergency surgical evacuation.1,4,5,31 In our study, all patients underwent emergency surgery to evacuate the traumatic hematoma and, of course, may have had associated underlying contusions or DI. We found that 30 patients with effacement of the basal cisterns spent higher percentages of hours with ICP higher than 20 mm Hg and CPP lower than 70 mm Hg. However, this did not influence patient outcome. Of 52 patients with patent basal cisterns at admission, 21 had compressed or absent basal cisterns and four continued to have a midline shift greater than 5 mm on postoperative CT scanning. In six patients with effacement of the basal cisterns the scans revealed normal cisterns after surgical evacuation, and all of these patients...
had a favorable outcome (Fig. 1). Subarachnoid hemorrhage and/or cerebral contusions are frequently associated with intracranial hematoma. Of our patients, 48 (59%) presented with these lesions and their presence had a strong influence on the appearance on the postoperative CT scan of DI III or IV (OR 4.81 [95% CI 1.8–12.7]; p < 0.001), an ICP higher than 20 mm Hg and a CPP lower than 70 mm Hg (p < 0.001), and patient outcome (OR 7.15 [95% CI 2.6–19.4]; p < 0.001). However, we found that after applying logistic regression, these associated intracranial lesions were not independent outcome predictors. The postoperative CT scan also revealed an increase in the size of preexisting contusions in most patients, and new lesions appeared in another 18 patients who did not have previous contusions (Fig. 2).

Early Postoperative CT Scanning

No investigator has evaluated the prognostic value of early CT scanning after surgical evacuation of an intracranial hematoma. We performed CT scanning within 2 to 12 hours after surgical evacuation of traumatic intracranial hematomas and found that patients with DI III or IV presented with a raised ICP and a CPP lower than 70 mm Hg more frequently than patients with DI I or II and that their combined mortality and mortality rate was higher (71.7% compared with 10.3%; p < 0.001). O’Sullivan, et al., reported on a group of eight patients with severe head injury and a normal initial CT scan (without mass lesion, midline shift, or abnormal cisterns). Most of these patients presented with elevated ICP and reduced CPP, and the authors suggested that patients with severe head injury and normal initial CT scans remain at substantial risk for development of significant secondary insults. In their study, the patients were connected to a computerized data collection system for continuous monitoring of arterial blood pressure, ICP, and CPP. In our study, 72% had at least one episode of elevated ICP (> 20 mm Hg) or lowered CPP (< 70 mm Hg) (48.3% in the DI I and II group and 96% in the DI III and IV group); however, the DI I and II group responded satisfactorily to treatment, maintaining for a short period of time ICP higher than 20 mm Hg (6.2 ± 9.6 hours) and CPP less than 70 mm Hg throughout the whole monitoring period; those patients survived with favorable outcomes. Therefore, we would recommend withdrawal of sedation and ICP monitoring in patients with DI I or II on postoperative CT scans when their ICP is normal. These data are similar to those obtained by Eisenberg, et al., in a National Institutes of Health Trauma Coma Data Bank study and by Narayan, et al.

When data obtained from the entire patient population were subjected to logistic regression analysis, an mGCS score of 3 or less, bilateral unreactive pupils, and DI III or IV on the postoperative CT scan were found to be significant independent predictors of poor outcome. Among these patients, age, one unreactive pupil, hypotension, and associated intracranial injuries did not independently and significantly affect outcome.

Fig. 2. A–D: Admission CT scans obtained in a 62-year-old patient revealing SAH, multiple contusions, and preserved basal cisterns. E–H: Postoperative CT scans demonstrating additional contusions and effacement of the basal cisterns (DI III).
Early CT scanning after traumatic hematoma

Conclusions
We have demonstrated that early CT scanning features following craniotomy are an independent predictor of outcome in patients with traumatic hematoma. Patients in whom DI III or IV was found on the postoperative CT scan and who presented with an mGCS score of 3 or less and nonreactive pupils were at higher risk for development of raised ICP requiring intensive treatment. For this reason we believe that continuous measurement of ICP and CPP postoperatively is advisable. Patients who presented with an mGCS score greater than 3, reactive pupils and CPP postoperatively is advisable. Patients who presented with an mGCS score of 3 or less and nonreactive pupils were at higher risk for outcome.

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References

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