Brain shift, level of consciousness, and restoration of consciousness in patients with acute intracranial hematoma

DONALD A. ROSS, M.D., WALTER L. OLSEN, M.D., AMY M. ROSS, R.N., M.S., BRIAN T. ANDREWS, M.D., AND LAWRENCE H. PITTS, M.D.

Departments of Neurological Surgery and Radiology (Neuroradiology), School of Medicine, University of California, San Francisco, and the Department of Neurological Surgery, San Francisco General Hospital, San Francisco, California

Recently, Ropper reported that horizontal brain shift caused by acute unilateral mass lesions correlated closely with consciousness, and suggested that recovery of consciousness was unlikely to occur after surgical evacuation if the shift was insufficient to explain the observed diminution of consciousness. The authors have sought to confirm the correlation of pineal shift with level of consciousness and to assess the prognostic value of brain shift measurements in a prospective study. Forty-six patients (19 with subdural hematoma, 14 with intracerebral hematoma, and 13 with epidural hematoma) were accrued to the study group consecutively. A correlation was found between a decrease in the level of consciousness and a significant increase in the mean lateral brain displacement at the pineal gland (from 3.8 to 7.0 mm) and septum (5.4 to 12.2 mm). When outcome was examined in patients who were stuporous or comatose on admission, a significant increase in septal shift was found among patients with a poor outcome, but there was no significant relationship between outcome and degree of pineal or aqueductal shift. A poor outcome was more likely with effacement of both perimesencephalic cisterns or the ipsilateral cistern, but not the contralateral cistern, although this difference did not reach statistical significance. These results do not substantiate the value of brain shift as an independent prognostic factor after evacuation of an acute unilateral mass lesion. The decision to operate and the determination of prognosis should be based rather on established criteria such as the clinical examination, age of the patient, and the mechanism of injury.

KEY WORDS: head injury • brain shift • intracranial hematoma • extradural hematoma • subdural hematoma

In 1986, Ropper reported that brain shift caused by unilateral mass lesions correlated closely with level of consciousness. Measured as the horizontal shift of the pineal gland, he reported the correlations as follows: with a 0- to 3-mm shift, the patient is alert; with a 3- to 4-mm shift, the patient is drowsy; with a 6- to 8.5-mm shift, the patient is stuporous; and with an 8- to 13-mm shift, the patient is comatose (Table 1). Careful evaluation of computerized tomography (CT) scans for evidence of uncal herniation and compression of the basal cisterns revealed that many patients were obtunded without evidence of transtentorial herniation, which suggested that brain shift itself or diffuse brain dysfunction rather than midbrain compression might be responsible for coma. Based on this evaluation, it was suggested that recovery of consciousness was unlikely to occur after evacuation of a mass lesion if the shift caused by the mass was insufficient to explain the observed diminution of consciousness. In an attempt to confirm the correlation of shift with level of consciousness and to assess the predictive value of brain shift in restoration of consciousness, a prospective study of 46 consecutive head-injured patients was conducted. Our results confirm the existence of a relationship between level of consciousness and the degree of brain shift, but shifts were generally larger in patients with poor outcomes.

Clinical Material and Methods

Patients with head injury admitted to the Neurosurgery Service at the San Francisco General Hospital were screened prospectively for admission to the study. Forty-six patients with acute unilateral hemispheric
Brain shift and prognosis following acute intracranial hematoma

Table 1: Classification of mental status*

<table>
<thead>
<tr>
<th>Classification</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>alert</td>
<td>spontaneous eye opening, converses, if not dysphasic</td>
</tr>
<tr>
<td>drowsy</td>
<td>eyes closed, easily aroused, sensible speech, rapid return to sleep without stimulation</td>
</tr>
<tr>
<td>stuporous</td>
<td>minimal arousal to vigorous stimulation, incoherent, purposeful response to painful stimulus</td>
</tr>
<tr>
<td>comatose</td>
<td>no eye opening, no speech, no purposeful response to pain</td>
</tr>
</tbody>
</table>

* Classification after the system of Ropper.10

Table 3: Mean brain shift reported by Ropper10

<table>
<thead>
<tr>
<th>Admission Mental Status</th>
<th>No. of Cases</th>
<th>Lateral Pineal Shift (mm)</th>
<th>Vertical Pineal Shift (mm)</th>
<th>Aqueductal Shift (mm)</th>
<th>Septal Shift (mm)</th>
<th>Uncal Herniation by CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>alert</td>
<td>10</td>
<td>1.4</td>
<td>1.8</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>drowsy</td>
<td>8</td>
<td>3.4</td>
<td>2.1</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stupor</td>
<td>6</td>
<td>6.8</td>
<td>4.0</td>
<td>11.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coma</td>
<td>4</td>
<td>9.8</td>
<td>7.7</td>
<td>14.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Outcome in surviving patients was determined at 3 months after operation. Patients whose status was judged to be less than alert by Ropper’s criteria were considered to have a poor outcome. Continuous variables were analyzed using the Student t-test or a one-way analysis of variance. Percentages were compared using the chi-square test.

Results

The clinical and CT data are summarized in Table 2. Of the 46 patients admitted to the study, 19 had acute subdural hematomas, 14 had intracerebral hematomas, and 13 had epidural hematomas. As the level of consciousness (measured by both the Ropper criteria and the Glasgow Coma Scale (GCS)) decreased, the amount of lateral brain displacement (measured at the pineal gland, aqueduct, and septum) increased. One-way analysis of variance showed a significant relationship between level of consciousness and lateral pineal or septal shift. There was no relationship, however, between vertical pineal shift and consciousness in these patients. As mental status declined, radiographic evidence of uncal herniation was more common but was not always seen. For comparison, Ropper’s results10 are summarized in Table 3.

Analysis of outcome for the 27 patients who were stuporous or comatose on admission showed a statistically significant correlation between outcome and septal shift and outcome and the GCS score recorded at admission, but no correlation was found for lateral

Table 2: Admitting level of consciousness and brain shift in 46 patients*

<table>
<thead>
<tr>
<th>Admission Mental Status</th>
<th>No. of Cases</th>
<th>GCS Score</th>
<th>Lateral Pineal Shift (mm)</th>
<th>Vertical Pineal Shift (mm)</th>
<th>Aqueductal Shift (mm)</th>
<th>Septal Shift (mm)</th>
<th>Uncal Herniation by CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>alert</td>
<td>8</td>
<td>15</td>
<td>3.8</td>
<td>0.4</td>
<td>0</td>
<td>1.4</td>
<td>0.5</td>
</tr>
<tr>
<td>drowsy</td>
<td>11</td>
<td>14</td>
<td>4.1</td>
<td>0.8</td>
<td>1.0</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>stupor</td>
<td>8</td>
<td>9</td>
<td>5.3</td>
<td>1.0</td>
<td>1.3</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td>coma</td>
<td>19</td>
<td>4</td>
<td>7.0</td>
<td>0.9</td>
<td>0.3</td>
<td>3.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

* GCS = Glasgow Coma Scale; SEM = standard error of the mean; CT = computerized tomography.
† One-way analysis of variance.
pineal shift, vertical pineal shift, aqueductal shift, or uncal herniation (Table 4). At 3 months after injury, 14 patients were alert, six were less than alert, and seven had died. When grouped by admission GCS scores, shifts were larger in patients with poor outcomes (Table 5). Effacement of both perimesencephalic cisterns correlated significantly with a poor outcome (Table 6). Patients with a poor outcome were 1.9 times more likely to have effacement of the ipsilateral cistern, but this did not reach statistical significance. While subdural hematomas were almost equally distributed between good- and poor-outcome patients, all three stuporous or comatose patients with epidural hematomas made a good recovery; however, only two of nine patients with intracerebral hematomas made a good recovery (Table 7). Mean shifts did not differ significantly when they were segregated by type of lesion (Table 7).

Discussion

A major goal of current clinical research on head trauma has been to define criteria that may be used to predict outcome in head-injured patients with altered mental status. Predictive ability would help medical staff to counsel family and friends of head-injured patients and perhaps help allocate expensive medical resources appropriately. In recent years, the GCS score has been the most widely used predictor of outcome. Attempts to improve the accuracy of predictions have considered additional factors such as age, intracranial pressure, nutrition, reflex eye movements, the type of intracranial lesion, the location of the lesion, magnetic resonance (MR) imaging, encroachment on the basal cisterns, and the brain-stem auditory evoked responses. The interaction of many effects has been studied using computer multifactorial analyses. It is obvious that outcome from acute brain injury depends on the complex interaction of a multitude of factors, and additional useful criteria are actively being sought.

The first description of the radiological significance of shift of the pineal gland has been attributed to Arthur Schüller and Howard Naffziger. Since Naffziger’s initial report published in 1924, pineal shift has been used widely as a diagnostic sign, but only recently has the amount of shift been related directly to state of con-
Brain shift and prognosis following acute intracranial hematoma

sciousness and prognosis. Ropper\textsuperscript{10} has suggested that when shift was appropriate to the observed depression of consciousness, recovery of consciousness after evacuation of a unilateral hemispheric mass lesion could be predicted. Conversely, if the shift caused by an acute mass lesion was not sufficient to explain a poor mental status, then evacuation of that lesion was unlikely to restore consciousness. Data collected prospectively in six patients were said to confirm that patients with a poor outcome would be expected to have smaller shifts than those with a good outcome. This hypothesis was tested prospectively in a series of 46 patients, 27 of whom were stuporous or comatose preoperatively, and the results do not substantiate the value of pineal shift as a factor predictive of restoration of consciousness after evacuation of a unilateral mass lesion.

In individual patients, a diminishing level of consciousness was associated with increasing lateral shift of the pineal gland, aqueduct, and septum. There was no apparent relationship between vertical pineal shift and consciousness in this group of patients; vertical shift of even one CT slice thickness was quite uncommon (occurring in two of the 46 patients).

While patients with a poor outcome actually had larger mean shifts, no significant differences in outcome were found at 3 months that were related to the size of lateral or vertical pineal shift, aqueductal shift, or radiological uncal herniation. Septal shift was significantly larger in patients with a poor long-term outcome. Marshall, \textit{et al.}\textsuperscript{8} reported that greater midline shift on CT scans correlated with a significantly lower likelihood of recovery. Only 12.5\% of patients with over 15 mm of shift recovered. While none of our patients had a pineal shift over 15 mm, all five patients with septal shifts over 15 mm had a poor outcome. This is consistent with the significantly larger mean septal shift found in our poor-outcome patients (Table 4). Conversely, no patient with less than a 5-mm septal shift and three (18\%) of the 17 patients with less than a 5-mm pineal shift had a poor outcome.

The lack of predictive value of pineal shift may be an artifact of our failure to identify on CT scans small lesions of clinical significance. Diffuse damage or injuries to critical midline structures can be detected on MR imaging, and many of our patients with a single lesion on CT scans might have shown multiple lesions on MR studies.\textsuperscript{15} Moreover, patients in whom shifts were not sufficient to explain diminished consciousness might have had other lesions that could not be detected on CT scans but could be seen by MR imaging. Poor neurological status in spite of little or no shift may be an indication for MR imaging, which would allow data collection on the natural history of these more subtle injuries.

A general but inconsistent relationship was found between the radiological diagnosis of uncal herniation and state of consciousness on admission. While only one of eight alert patients had CT evidence of herniation, 23 of 37 patients with altered mental status had such evidence. Radiological herniation may mean that more severe brain injury is imminent, but the mere presence of this lesion did not influence outcome (Table 4).

The present results show that patients with poor outcome had a lower GCS score, which is consistent with the known relationship.\textsuperscript{6} Similarly, the type of lesion affected outcome: patients with epidural hematomas generally did well but patients with a poor mental status and intracerebral hematomas did poorly.\textsuperscript{12,14} Effacement of the perimesencephalic cisterns also correlated with outcome, a finding reported by Toutant, \textit{et al.}\textsuperscript{13} In our series, 69\% of patients with both cisterns effaced had a poor outcome, while 29\% of patients in whom neither cistern was effaced had a poor outcome.

It is of interest that compression of the ipsilateral perimesencephalic cistern was more likely to be associated with a poor outcome than compression of the contralateral cistern. Effacement of the contralateral basal cisterns while the ipsilateral cisterns remain open may indicate a disproportionate shift of both hemispheric and brain-stem structures to the contralateral side; effacement of the ipsilateral cisterns, however, may signify a disproportionate shift of hemispheric structures over brain-stem structures, which may produce relatively more compression or distortion of vital midline structures. Factors such as the size and shape of the tentorial incisura and the rate of development of the shift may affect the ability of the brain stem to accommodate these changes. Rapid development of a hemispheric mass or a relatively tethered brain stem would produce more ipsilateral cistern compression, while a slow shift or a relatively mobile brain stem would compress the contralateral cistern.

In conclusion, this study demonstrated the relationship between increasing brain shift and diminished consciousness, but a pineal shift was not found to be of value in predicting restoration of consciousness after evacuation. A discrepancy between shift and mental status should not, however, alter the decision to operate upon an acute unilateral hemispheric mass if surgery is indicated based on other factors such as age, mechanism of injury, type of lesion, location of lesions, GCS score, complicating hemodynamic and pulmonary factors, time to definitive care, or results of intracranial pressure monitoring. Such a discrepancy may be an indication for MR imaging. Large septal shifts and effacement of the perimesencephalic cisterns are poor prognostic factors.

References

3. Braakman R, Habbema JDF, Gelpke GJ: Prognosis and

\textit{J. Neurosurg.} / Volume 71 / October, 1989 501
prediction of outcome in comatose head injured patients.


Manuscript received June 1, 1988. Accepted in final form April 17, 1989.

Address reprint requests to: Donald A. Ross, M.D., c/o The Editorial Office, 1360 Ninth Avenue, Suite 210, San Francisco, California 94122.