Isotope Cisternography in Patients with Intracranial Hypertension

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Cerebrospinal fluid flow (CSF) was studied using isotope cisternography in 52 patients with increased intracranial pressure (ICP), all of whom showed acute transient rises of ICP, i.e., plateau waves, in their continuous ICP recordings. The patients were assigned to two groups. Group I was comprised of 23 patients without hydrocephalus and high ICP resulting from brain tumors, benign intracranial hypertension, and superior sagittal sinus thrombosis. Group II included 29 patients with either communicating hydrocephalus or high ICP resulting from rupture of intracranial aneurysm. Plateau waves were frequently observed in patients with baseline pressures ranging from 21 to 40 mmHg in both groups. The isotope cisternographic pattern in the Group I patients showed a large accumulation of radioactivity over the cerebral convexities, while that in the Group II patients revealed a complete obstruction of the subarachnoid space over both cerebral convexities. The isotope clearance from the intracranial CSF showed a marked delay in both groups of patients with one exception. The results suggest that, in the limited range of increased ICP caused by delayed CSF absorption, plateau waves are most evident regardless of the isotope cisternographic pattern.


Plateau waves, first described by Lundberg, (1), can often be observed in patients with increased intracranial pressure (ICP) resulting from brain tumors, benign intracranial hypertension, hydrocephalus, and other causes (1–6). Typical plateau waves are characterized by a sudden increase of the ICP to values of 50–100 mmHg, continuation of this pressure for a period of time (usually 5–20 min) and then a rapid fall to the original level or below (1). The origin of plateau waves has yet to be clarified and is of considerable interest to neurosurgeons. Clinically, plateau waves have not been observed in hydrocephalic infants with open fontanels and increased ICP. Furthermore, such waves have been found to diminish or disappear after subtemporal decompression in spite of the ICP remaining at about the same level as before the operation. From these observations, Lundberg suggested that two conditions must be fulfilled for the development of plateau waves; namely, a closed cranial cavity with rigid walls and persistent intracranial hypertension, i.e., rigid conditions within the cranial cavity (7). As for these rigid conditions, we suggested in the preliminary report that the reduction of the intracranial cerebrospinal fluid (CSF) absorption might play an important role (2). In the present study, we analyzed isotope cisternography in 52 patients with high ICP and association of plateau waves in an attempt to confirm the role that the CSF dynamics may play in the development of plateau waves.

MATERIALS AND METHODS

Patients

The series consisted of 52 patients with increased ICP and the association of plateau waves in their continuous ICP recordings. Twenty-two were men and 30 were women. Their ages ranged from 21 to 68 yr, with a mean of 51 yr.

Protocol

The patients were assigned to two groups based on the presence or absence of communicating hydrocephalus. Group I comprised 23 patients without hydrocephalus and with high ICP resulting from brain tumors (15 cases), benign intracranial hypertension (five cases), and superior sagittal sinus thrombosis (three cases). Group II included 29 patients with either communicat-
ing hydrocephalus or high ICP resulting from rupture of intracranial aneurysm. The sites of the ruptured aneurysms were as follows: 12 were associated with the anterior communicating artery, nine with the internal carotid artery, five with the middle cerebral artery, and three with the vertebrobasilar artery.

**Intracranial Pressure Recordings**

The ICP was recorded through an indwelling ventricular catheter attached to a pressure transducer (Fig. 1). The recording method used was based on that described by Lundberg (1). The ICP was continuously recorded on a polyrecorder for a period ranging from 25 to 48 hr. Plateau waves were as described by Lundberg (1), i.e., plateau-like formations recurring at varying intervals. In this study, high ICP is defined as having a resting pressure of more than 15 mmHg for 50% or more of the study period (3,4).

**Isotope Cisternography**

Isotope cisternography was performed with a lumbar injection of 1 mCi of indium-111-diethylenetriaminepentaacetic acid. Sequential lateral and posterior scintiscans of the head were obtained with a scintillation camera at ~2, 6, 24, and 48 hr after injection. The intracranial isotope activity at each interval was calculated with correction of environment background and decay. The corrected head count rate was then normalized with respect to the peak level of activity and expressed as a percentage of this maximum value. Clearance of the CSF was defined by the occurrence of peak isotope activity and the level of residual activity at 2, 6, 24, and 48 hr. The cisternography was carried out just prior to or just after continuous ICP recordings.

**TABLE 1**

Range of Baseline Intracranial Pressure (ICP) and Number of Patients with Plateau Waves

<table>
<thead>
<tr>
<th>Baseline ICP (mmHg)</th>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11–20</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>21–30</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>31–40</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>41&lt;</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td><strong>29</strong></td>
</tr>
</tbody>
</table>

**Computed Tomography**

Computed tomography (CT) examinations were performed, and the ventricular score was calculated according to the method of Taveras and Morello (8). The method consists of adding (a) the distance from the head of the caudate nucleus to the anterior end of the septum pellucidum on each side, (b) the distance between the two lateral ventricular margins at the foramen of Monro, (c) the width of the third ventricle, and (d) the span of the two lateral ventricles as they approximate each other in their narrowest central portion. The sum of these distances is then related to the maximum interparietal diameter, measured as the inner table, and the ratio is multiplied by 100. This value is between 36 and 48, with a mean of around 42, in normal subjects (8). In this study, patients diagnosed as having hydrocephalus had a dilated ventricular system on the CT findings, and the score was between 55 and 83, with a mean of 64.

**RESULTS**

**Intracranial Pressure Level and Plateau Waves**

Table 1 shows the baseline pressure obtained from continuous ICP recording and the number of patients in Group I and II in this study. Plateau waves were most frequently observed in patients with baseline pressures ranging from 21–40 mmHg in both groups.

Plateau waves in Group I were characterized as large plateau-like formations with a height of 50–100 mmHg and a duration of 10 to 30 min, recurring frequently at varying intervals. Figure 2 demonstrates typical plateau waves in a patient with benign intracranial hypertension in this group.

Plateau waves in Group II had a height of 20 to 60 mmHg, a duration of 3–15 min and appeared frequently at varying intervals. The waves in this group were smaller in amplitude and shorter in duration than those observed in Group I. Although there was a difference in the height and duration of the waves between the two groups, the waves had otherwise similar char-
characteristics. Figure 3 shows the ICP recording in a patient in this group. Frequent plateau waves are observed.

Isotope Cisternographic Findings

The sequential images of isotope distribution and its clearance were studied in all Group I and II patients. The isotope cisternographic pattern in Group I patients showed a large accumulation of radioactivity over the cerebral convexities in the 24- and 48-hr images, but no blockage of the subarachnoid space. Nine patients in this group, however, showed transient ventricular filling in the early images (2- or 6-hr images, or both).
FIGURE 4
Isotope cisternogram of same patient as in Fig. 2. There is no blockage of subarachnoid space, but visualization of subarachnoid space over cerebral convexities and ventricular filling was noticed at 2- and 6-hr images, followed by large accumulation of radioactivity over both cerebral convexities at 24- and 48-hr images. Peak isotope activity is reached at 24 hr, suggesting delay of CSF flow. Intracranial isotope activities (counts) at each interval are indicated under each interval time.
Figure 4 shows a cisternographic pattern at each interval in this group (the same patient as in Fig. 2). On the other hand, the pattern in Group II patients showed complete obstruction of the subarachnoid space over both cerebral convexities and persistent visualization of the enlarged ventricles. Figure 5 demonstrates a cisternographic pattern at each interval in this group (the same patient as in Fig. 3).

![Cisternographic images](image_url)

**FIGURE 5**
Isotope cisternogram of same patient as in Fig. 3. There are complete obstruction of subarachnoid space and marked delay of isotope clearance from head. Intracranial isotope activities at each interval are indicated under each interval time.
TABLE 2  
Mean Values of Normalized Head Count Rates of Isotopes at Each Interval in Group I and II Patients

<table>
<thead>
<tr>
<th>Intracranial isotope activity (% of maximum)</th>
<th>2 hr</th>
<th>6 hr</th>
<th>24 hr</th>
<th>48 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (n = 23)</td>
<td>23 ± 6</td>
<td>64 ± 18</td>
<td>100 ± 0</td>
<td>70 ± 19</td>
</tr>
<tr>
<td>Group II (n = 29)</td>
<td>36 ± 12</td>
<td>70 ± 19</td>
<td>98 ± 8</td>
<td>63 ± 21</td>
</tr>
</tbody>
</table>

The head count rates of isotopes at 2, 6, 24, and 48 hr studied in both groups showed that the peak activity was not reached until 24 and 48 hr, in any of the patients with one exception in Group II. Table 2 and Figs. 6 and 7 show the mean values of head count rates of isotopes calculated at each interval for the Group I and II patients with a range of ±1 s.d. One patient in Group II showed maximal intracranial activity at 6 hr followed by a gradual decrease to levels of 80 and 34% of peak activity at 24 and 48 hr, respectively. The ventricular dilatation on the CT in this patient was mild, and the ventricular score was 58.

Estimated Rate of Cerebrospinal Fluid

During the course of the ICP recording, temporary drainage of the CSF was undertaken to reduce the increased ICP in 12 patients in Group I and 20 in Group II. The mean rate of CSF formation was calculated by dividing the drained CSF volume by the time taken to return to the predrainage level (5) and was ascertained to be 0.33 ml/min in the Group I patients and 0.30 ml/min in the Group II patients (Table 3).

DISCUSSION

Two major factors have been proposed for the development of plateau waves in patients with intracranial hypertension. They are a cerebral vasomotor reaction and a tight intracranial condition (1). As for the first factor, it has been shown that the elevation of the ICP at the beginning of the plateau wave is caused by dilatation of the cerebral vessels, while the subsequent decline is caused by constriction of these vessels (1,7, 9–11). As to the second factor, we suggested that the intracranial CSF might play an important role in the development of the tight conditions (2,4).

Previously, the role of the CSF in the production of plateau waves was believed to be as follows: the CSF may be squeezed out from the intracranial fluid spaces during either rising or plateau of the wave, and the CSF space may be refilled between the waves until the next wave begins (7). This assumption, however, suggests that the intracranial CSF may act as a variable in the development of the plateau waves. Risberg et al. claimed that, although under normal conditions the CSF may act as a mechanical buffer for the ICP varia-

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FIGURE 6
Normalized isotope activity after lumbar intrathecal injection of isotopes in Group I patients

FIGURE 7
Normalized isotope activity after lumbar intrathecal injection of isotopes in Group II patients
ity lakes was slow and complete over a series of days until its final disappearance from the central nervous system. Isotope cisternography in patients with communicating hydrocephalus had three basic phenomena, i.e., blockage of the CSF pathways, ventricular filling, and delayed absorption (13). In the present study, the cisternographic pattern in the Group I patients showed a large accumulation of radioactivity over the cerebral convexities, while that in the Group II patients showed complete obstruction of the subarachnoid space and persistent visualization of the enlarged ventricles. Thus, the cisternographic patterns between the two groups were quite different.

Curl et al. (14) stated that the peak isotope activity as revealed by cisternography in nonhydrocephalic and normal clearance patients demonstrated maximum intracranial isotope activity at 6 to 12 hr, followed by a gradual decrease to levels between 40 and 80% of peak activity at 24 hr and 25 to 40% at 48 hr. In the present study, the peak isotope activity was not reached at 24 to 48 hr after the isotope injection in any of the patients in either group with one exception, suggesting a marked delay of CSF absorption.

Plateau waves were most frequently observed in patients with elevated baseline pressure ranging from 21 to 40 mm Hg in both groups. The cisternographic finding that was common to the Group I and II patients was a markedly delayed clearance of the intracranial CSF. The estimated rate of CSF formation was 0.33 ml/min in Group I patients and 0.30 ml/min in Group II patients, a rate near the normal secretion of 0.37 ml/min in adults (15). The results suggest that, although the delayed CSF clearance with the normal CSF secretion causes several degrees of increased ICP, the incidence of plateau waves are most evident with the ICP in the limited range of elevated ICP irrespective of the isotope cisternographic pattern.

REFERENCES


