OBSERVATIONS ON ENCEPHALOGRAPHIC FINDINGS IN CEREBRAL TRAUMA

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The authors have had opportunity for studying encephalograms done in an Army Hospital serving as a neurological and neurosurgical center over a period of nine months. The majority of cases were post-traumatic. It is believed in view of the rather limited data available in the literature on similar studies the findings at this installation are of sufficient value to be recorded.

MATERIAL STUDIED

During the period mentioned above, 261 patients were examined by lumbar encephalograms. Of these, 177 had head injury with skull defects, while 29 had closed head injuries, making a total of 206 cases, or 79 per cent. There were 32 with idiopathic epilepsy, and in 23 cases examination was made for other lesions of the central nervous system. The x-ray reports were available in all cases, and the actual films were available for review and for special measurements used in this study in 193 cases, 159 of which were cases of head injuries. In some instances the clinical records were not available at the time of study.

DESCRIPTION OF TECHNIQUE

Encephalographic procedures at this hospital have been carried out entirely in the radiological department.

Examinations were done in the afternoon. The patient was prepared by omitting the noon meal and giving pre-anesthetic medication in appropriate dosage one to two hours prior to the procedure. Premedication usually consisted of morphine, gr. ¼ and scopolamine, gr. 1/150. All encephalograms were done under intravenous anesthesia. Sodium pentobarbital (3/4 per cent solution) was used, the total dose varying with the individual.

When ready for the procedure, the patient was placed on a support attached to an ordinary radiographic tilting table with the table in vertical position. The support consisted of a board fastened to metal arms which could be attached to the table in the manner of the usual foot-board. The patient was arranged in the sitting position with his left side against the surface of the table, arms extended and resting on a small bedside table, which could be adjusted to the proper height. The head was placed with the chin resting on a U-shaped support on the bedside table.

The two-needle method of drainage of the cerebrospinal fluid was used, one needle being inserted between the 2nd and 3rd lumbar vertebrae and the second one between the 3rd and 4th lumbar vertebrae. The fluid was permitted to escape freely, each 20 cc. of fluid being replaced with 30 cc. of air. As much fluid was removed as possible, usually 100 to 150 cc.

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being withdrawn. It was not felt necessary to resort to manipulation of the head. This method was used because it was believed that a freer interchange of fluid and air was possible and that more complete and somewhat quicker drainage could be obtained.

After drainage was completed, anesthesia was discontinued, the table was returned to horizontal position, the support removed and radiographs were taken immediately.

In all cases a complete series of roentgenograms was made, consisting of anteroposterior, posteroanterior, and both lateral stereoscopic views. Except in unusual cases where it was felt that further information might be obtained, the vertical position was not used. During the taking of the films a standard head-support attached to the radiographic table was employed to maintain position and fixation of the head. Wedge-shaped supports were used beneath both shoulders for the PA view and beneath the contralateral shoulder for the lateral view.

The usual radiographic technique consisted of the use of the Potter-Bucky diaphragm, intensifying screens and a target film distance of 36 inches. Radiographic factors were: Kilovoltage, 70; Milliamperes, 100. The time was varied in individual cases as indicated, the average patient requiring 0.4 second for lateral views and 0.8 second for AP and PA views. The films were developed immediately and checked for the necessity of any further study as well as for technical quality before the patient left the department.

INDICATIONS AND CONTRAINDICATIONS

I. Indications

(A) Any head injury with sequelae
   1. Penetrating head wound
   2. Depressed fracture
   3. Simple fracture
   4. Post-traumatic symptoms without demonstrable injury to vault

(B) Convulsive seizures
   1. Epilepsy with deterioration
   2. Focal seizures
      a) Focal tracings in electroencephalogram
      b) Localizing neurological signs
   3. Convulsive seizures beginning after the age of 30
   4. Post-traumatic convulsive seizures

(C) Signs or symptoms of degenerative cerebral disease

(D) Suspicion of brain tumor without signs of increased intracranial pressure

II. Contraindications

(A) Absolute—presence of choked disc

(B) Usually—other clinical or x-ray signs of increased intracranial pressure

METHOD OF MEASUREMENT

Early in the course of this study it became obvious that some objective method of measurement of ventricular size would be useful. It was felt that measurement would (1) aid in obviating the factor of personal judgement in analyzing encephalograms for evidence of dilatation, (2) form a basis of comparison between cases, and (3) provide comparison between repeat examinations in the same case.
Various measurements were considered, but the most satisfactory standard for our purpose was found to be the size of the body of the lateral ventricle on the AP view from the superior medial angle to the closest point on the inferolateral walls of the ventricle. A similar measurement was used by Paul and Erickson in a study recently reported. This measurement was recorded on a series of 168 encephalograms with satisfactory filling of the ventricles and subsequently correlated in the individual cases with the impression as to the size of the ventricles. Establishment of a norm is difficult, but taking normal controls and the clinical picture into consideration, the following limits were established and found to be helpful during the course of the study.

(1) 1.1 cm. and below, definitely normal

(2) 1.2cm. to 1.4 cm., usually normal

(3) 1.5 cm., borderline

(4) 1.6 cm. and above, definitely dilated.

Two other measurements were considered and used in some cases. One was the measurement of the width of the upper border of the lateral ventricle from the medial to the lateral angle. It was found that this compared favorably in accuracy with that described above but ordinarily gave no additional information. The third was an attempt to measure the width of the anterior horns, and was the distance from the superior medial angle of the lateral ventricle to the lateral wall of the anterior horn taken at approximately a 30° angle from the horizontal. It was found to be less reliable than the other measurements but served its purpose well in comparison of first- and second-day films, which is being considered in a separate study.

It was realized that validity of such measurements might be questioned on the basis of change in position of the head or the x-ray tube during the taking of roentgenograms, particularly since in many cases they were used for comparison between the first- and second-day films. In order to determine their accuracy against this factor, additional films were taken in several cases, first varying the degree of tilting of the tube up to 10° from the usual angle in both directions, second with slight rotation of the head in both directions and third, comparative studies on stereoscopic pairs. In no instance was the variation more than 0.2 cm. from film to film of the same case taken on the same day. Reexamination in two cases done several weeks apart showed no greater variation from the original figures.

The faults inherent in any method of measurement of the ventricular system are well recognized; nevertheless some standard would appear to be desirable. It is believed that the method used is satisfactory because: (1) the measurements are easily obtained from a single film, (2) they can be reproduced in the same patient with a standard technique, (3) they are sufficiently reliable for ordinary purposes, (4) they measure the width of the body rather than one of the horns of the ventricle, and (5) they are more dependable than other measurements in the presence of minor deviations from the standard projection.
FAILURE OF VENTRICLES TO FILL

Failure of the ventricles to fill is not necessarily an indication of pathology. Lemere and Barnacle, in reviewing 800 encephalograms, found that the ventricles did not fill in 8 per cent of their cases. Mayfield and Bell place the percentage of nonfilling at 4–8 per cent.

In the series of 261 encephalograms reviewed here, the cases are divided into three groups: those showing satisfactory filling, poor filling, and no filling. Satisfactory filling was shown in 227 (87.5 per cent), poor filling in 15 (5.5 per cent), and no ventricular filling was revealed in 19 (7 per cent). The distribution of the type of filling among the various groups studied is shown in Table 1.

### Table 1

<table>
<thead>
<tr>
<th>Type of Cases</th>
<th>Satisfactory Filling</th>
<th>Poor Filling</th>
<th>No Filling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head injury with skull defect</td>
<td>160</td>
<td>8</td>
<td>9</td>
<td>177</td>
</tr>
<tr>
<td>Head injury without skull defect</td>
<td>23</td>
<td>1</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>Idiopathic epilepsy</td>
<td>27</td>
<td>9</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>Others</td>
<td>15</td>
<td>3</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>227</strong></td>
<td><strong>15</strong></td>
<td><strong>19</strong></td>
<td><strong>261</strong></td>
</tr>
</tbody>
</table>

The reasons for the failure of the ventricles to fill are unknown. On many occasions a second attempt at encephalography, carried out under precisely the same conditions as the first, will produce satisfactory filling. Grant stresses that complete replacement of cerebrospinal fluid by air should be attempted and such replacement was attempted in all cases in this series.

In an attempt to correlate the adequacy of filling of the ventricular system with the amount of fluid replaced, the cases were divided into those in which over 150 cc. of fluid had been replaced and those in which replacement had been less than 150 cc. There were 142 case records available for this portion of the analysis. In 58 the amount of replacement was 150 cc. or more: 55 (95 per cent) showed satisfactory filling, 1 (2 per cent) poor filling, and 2 (3 per cent) no filling. Of the 84 cases in which replacement of fluid was less than 150 cc., 71 (84 per cent) revealed satisfactory filling, 4 (5 per cent) poor filling, and 9 (11 per cent) no filling. It would thus seem that the amount of replacement of cerebrospinal fluid by air has a definite relationship to the completeness of the filling of the ventricles. However, it is possible that ventricles markedly dilated as a result of cerebral atrophy fill more easily and completely than do normal or less markedly dilated ventricles.

Because of the transfer of patients to other installations with consequent loss of their records, it was impossible to further analyze the failure of the ventricles to fill, but it is stressed that in every case an attempt was made to completely drain the cerebrospinal fluid.
NORMAL AND ABNORMAL VENTRICULAR SYSTEMS

In 168 cases of all types the ventricular filling was satisfactory and the films were available for review. The encephalograms were abnormal in 117 cases and normal in 51. The distribution of normal and abnormal encephalograms among the types of cases studied is shown in Table 2.

<table>
<thead>
<tr>
<th>Type of Cases</th>
<th>Normal</th>
<th>Abnormal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head injury with skull defect</td>
<td>34</td>
<td>96</td>
<td>130</td>
</tr>
<tr>
<td>Head injury without skull defect</td>
<td>4</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Idiopathic epilepsy</td>
<td>7</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Others</td>
<td>6</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>51</td>
<td>117</td>
<td>168</td>
</tr>
</tbody>
</table>

Shift of the Ventricle System

Of the 143 cases of head injury in which filling of the ventricles was satisfactory and the films and clinical records were available, 17 (12 per cent) showed a shift of the ventricular system towards the side of the cranial defect. Hauptmann, Travers and others attribute this shift entirely to cortical fibrosis. Crothers and Wyatt, in reviewing 1700 encephalograms performed on children with atrophic lesions, noted the frequent shift of the ventricles toward the atrophic side and felt that the mechanism was a pushing over of the growing normal hemisphere to the atrophic side.

Considering the short time elapsed between injury and examination in most of the cases reviewed here, it seems unlikely that fibrosis played a significant role in the displacement. It is believed that a shifting and expanding of the remaining brain helped occupy the space resulting from extensive loss of cerebral substance and was the cause of the shift of the ventricles.

Symmetrical Enlargement of the Lateral Ventricle and the Third Ventricle

In 12 (8.5 per cent) of the 143 cases of cranial trauma there was symmetrical enlargement of the lateral and third ventricle. Two patients with epilepsy (not traumatic) also showed this type of ventricular dilatation. The mechanism of such dilatation is debatable, but it seems most likely that in the majority of cases it is due to generalized loss of cerebral substance with secondary dilatation of the cerebrospinal system.

However, in some cases of cerebral trauma where diffuse bleeding throughout the subarachnoidal system undoubtedly occurred, with secondary fibrosis, the factor of deficient absorption of fluid must be considered. In the majority of cases of open head injury the subarachnoidal markings were absent around the defect, indicating that at least a portion of the
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absorbing mechanism was not functioning. If this obliteration of the subarachnoidal spaces were sufficiently wide-spread, the factor of obstruction with consequent internal hydrocephalus would be an important one. The fourth ventricle would also be dilated, but, unfortunately, by any routine encephalographic procedure the fourth ventricle is not well visualized.

The findings and cases reviewed here would indicate that while the partial obliteration of the subarachnoidal spaces with consequent deficiency of cerebrospinal-fluid absorption may play some part in the symmetrical ventricular dilatation, the principal etiology of such dilatation is diffuse loss of cerebral substance. In agreement with this conclusion are the findings in two cases of epilepsy showing such enlargement in conjunction with normal subarachnoid patterns.

*Symmetrical Enlargement of the Lateral Ventricle without Enlargement of the Third Ventricle*

Eleven (8 per cent) of the 143 cases of cranial trauma revealed enlargement of both lateral ventricles without enlargement of the third ventricle. The underlying mechanism of such dilatation is most likely diffuse cerebral atrophy secondary to trauma.

*Bilateral Asymmetrical Enlargement of the Lateral Ventricles*

In 41 (29 per cent) of the 143 cases of cranial trauma bilateral asymmetrical enlargement of the lateral ventricles was evident. Of these, 31 (75 per cent) also showed dilatation of the third ventricle, whereas in the remaining 10 (25 per cent) the third ventricle seemed normal. The side of the greatest enlargement of the lateral ventricle was always the side of the injury in both open and closed head injuries.

*Unilateral Enlargement of the Lateral Ventricle*

In 42 (29 per cent) of the 143 cases of cranial trauma there was enlargement of only one lateral ventricle. The mechanism of such enlargement is most likely direct loss of cerebral substance without diffuse cerebral change.

*Second-Day Encephalographic Studies*

In 60 cases the appearance of the ventricles was checked on the day following the encephalography.* These follow-up studies proved interesting. They showed some enlargement of the ventricles in more than one-third of the cases. The enlargement was marked at times. Some porencephalic cysts, not visible during the first day examination, became visible on the later films. At times a peculiar bulging of the interventricular septum was found on the second day. These studies were of theoretical and practical interest. The existing brain atrophy was at times much more obvious on the second

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* Schatzki, R., Baxter, D. H., and Troland, C. E. Second-day encephalography with particular emphasis on size of ventricles. (To be published)
day and the differential diagnosis between a space-occupying process and atrophy was facilitated in some cases by the follow-up study.

**CORRELATION BETWEEN TIME OF INJURY AND VENTRICULAR ENLARGEMENT**

There were 126 cases of cranial trauma, both cranial defects and closed head injuries, divided into groups according to length of time between time of injury and encephalography. Only those cases were reviewed in which the exact time of injury was known and the encephalographic pictures were excellent. In 33 (26 per cent) injury had been sustained less than three months before encephalography and of these, 20 (60 per cent) showed ventricular enlargement of some type.

Mayfield and Bell\(^{10}\) and others state that shrinkage of the brain following injury is not demonstrable for three to four months after the injury. The mechanism of the shrinkage is not definitely known. It might be due to impaired circulation or to fibrosis and contracture following injury, and it is probable that both of these factors play some part in ventricular dilatation at the injury. However, the principal mechanism is probably simple loss of brain substance, perhaps mainly lipoids. This fact is indicated by the early dilatation (less than three months) in 60 per cent of the cases available.

We believe that ventricular enlargement can be demonstrated in a majority of cases within a very short time after injury, that is, as soon as cerebral edema consequent upon the injury has subsided.

**CORRELATION OF NEUROLOGICAL FINDINGS AND ENCEPHALOGRAMS**

Of 129 cases of cranial trauma in which filling of the ventricles was satisfactory and there was adequate clinical information on the neurological side, 11 (8.5 per cent) revealed a normal ventricular system in the presence of clinical evidence of definite neurological damage. In 61 (47.5 per cent) there was positive evidence of neurological damage and abnormal encephalogram while 26 (20 per cent) had no clinical or encephalographic evidence of cerebral damage. In 31 (24 per cent) the encephalogram was abnormal although neurological examination was negative.

The neurological examination in many cases was relatively gross as it was confined to examination of the motor and sensory systems, the visual fields, reflex changes, gross dysphasia and the cranial nerves, without adequate psychiatric study or an estimation of any mental retardation. If these two studies had been carried out it is believed that the percentage of cases showing clinical evidence of cerebral damage would be somewhat higher than the above figures would indicate.

The clinical record in many cases, particularly as concerned neurological status soon after injury, was too inadequate for a statistical correlation of neurological and encephalographic findings but certain broad impressions and findings could be gathered. For the most part the encephalogram and the clinical findings were very closely related. This was particularly true in cases of unilateral ventricular dilatation where the cerebral loss was rela-
tively circumscribed and the clinical picture was that of localized cerebral damage.

If the occipital or temporal regions showed dilatation there were field defects of varying sizes, and if the cerebral loss was mainly in the Rolandic region there were varying degrees of motor paralysis. Few patients, however, showed persistent sensory defect although there was encephalographic evidence of severe damage to the sensory cortex. Sensation in the great majority of cases had been largely taken over by the opposite cortex or lower centers.

The degree of motor paralysis and spasticity varied greatly in patients showing essentially the same encephalographic picture. It had been hoped that it might be possible to more closely correlate the degree of spasticity with the encephalographic picture but this was not possible because of lack of sufficient data. The impression was gained, however, that spasticity was most pronounced in those cases showing cerebral damage anterior to the Rolandic area along with damage to the motor area.

In some cases there was considerable variation in the clinical picture in the presence of essentially similar encephalographic findings. This was particularly true in cases of extensive generalized ventricular dilatation, some showing definite evidence of cerebral impairment while in others the changes were very meager.

POST-TRAUMATIC SYNDROME

In 123 cases the encephalographic fillings were satisfactory and information was available as to post-traumatic symptoms. In this group 116 patients had cranial defects, and 7 had closed head injuries. The number of closed head injuries in this series is of course too small for a statistical study. Six of the 7 patients had severe post-concussion syndromes consisting of headache, dizziness, intolerance to alcohol and some memory loss. Four of these 6 had normal encephalograms. Of the 116 patients with cranial defects, 47 (41 per cent) had post-traumatic symptoms (headaches, dizziness, etc): 14 (29 per cent) of these had normal encephalograms. There were 69 (59 per cent) who had no post-traumatic symptoms.

The post-traumatic syndrome in cases of cranial defects was almost always very mild, usually consisting of a slight headache. In the closed head injuries the syndrome was always very pronounced, but no conclusions can be drawn from this fact as only the more severe closed head injuries are seen in a general hospital and only a small percentage of these cases are submitted for encephalography.

The post-traumatic syndrome has been regarded by many as a purely psychiatric manifestation. However, Mayfield and Bell, Friedman, Travers, Hauptmann and others have shown definite encephalographic changes following closed head injuries in patients having post-traumatic symptoms but no localizing neurological signs. Their findings and the few cases in this series would indicate that encephalography should be used more widely
in post-traumatic cases, in order to ascertain the presence of definite cerebral damage. A normal encephalogram does not necessarily rule out organic brain damage but it does indicate that such damage is probably not severe.

Encephalography has been reported by many authors to give relief of post-traumatic symptoms but in this series the amount of relief was meager and minimal.

SUMMARY

1. The encephalographic findings in a series of 261 patients, 206 of whom had had cranial trauma, have been reviewed. Of these, 177 had head injuries with skull defects while 29 had closed head injuries.
2. Abnormal encephalograms were found in 74 per cent of the cases of head trauma.
3. Unilateral dilatation of the ventricles was found in 29 per cent of the cases of head trauma. Symmetrical bilateral dilatation of the ventricles was found in 16 per cent of these cases; asymmetrical bilateral dilatation in 29 per cent.
4. In a group of 60 cases in which second-day study of the ventricles was made, an increase in the ventricular size on the second day was found in over one-third.
5. Many of the encephalographic abnormalities were found within a short time after injury.

REFERENCES