Electroencephalographic findings in hydrocephalic children prior to initial shunting

Anna-Liisa Saukkonen
Department of Pediatrics, University of Oulu, SF-90220 Oulu, Finland

Abstract. The EEG recordings of 105 hydrocephalic children with proven ventriculomegaly and increased intracranial pressure were studied prior to initial shunt treatment. Only 2 patients had a normal EEG and 7 had only abnormal dominant activity. Paroxysmal slow-wave activity, generalized or posterior, was present in 37 (35% of the patients) recordings and focal slow waves in 28 patients (27%), these mostly posterior. All types of slow-wave activities increased with age. Focal attenuation was very common under 1 year of age (in 41% of patients of this age group), but after this age only 4 cases (10%) were recorded. Spike-or sharp-wave activity was recorded focally or generally in 45 (43%) of the children. The prevalence of spikes and sharp waves correlated negatively with increasing age: only generalized spikes were usual after 7 years of age. No significant differences were found in the appearance of focal findings between hemispheres. According to the present study, the EEG is abnormal in more than 98% of children with proven hydrocephalus before shunting. The observed abnormalities are described in detail in order to serve as reference material in the follow-up of hydrocephalic children.

Key words: EEG - Hydrocephalus - Epilepsy - Shunt treatment - Increased intracranial pressure - Ventriculomegaly.

The diagnosis and follow-up of hydrocephalus has traditionally been based on invasive investigations such as ventriculography, pneumoencephalography, angiography, and direct intraventricular pressure registration. Today these have almost completely been replaced by computed tomography and ultrasonography, whereas magnetic resonance imaging (MRI) will probably be the future method of choice. The out-dated invasive methods were particularly laborious and risky. For follow-up, computed tomography may not be the ideal tool due to increasing radiation doses and high cost. The use of ultrasound is restricted to infants with an open fontanel.

The EEG is a noninvasive investigation that can be reliably repeated without limits and with no adverse effects. Therefore, the EEG may serve as part of the systematic follow-up of shunt-treated children. When the EEG is used in follow-up, an EEG recording made prior to surgical intervention is valuable, as this forms the basis for comparison with later recordings. However, the value of EEG findings in the evaluation of children with hydrocephalus has been briefly documented [3, 5, 10, 12]. The follow-up reports are mostly concentrated on evaluating epileptic activity following shunt treatment [1, 2, 7, 8, 13, 15, 16]. Furthermore, the value of the initial EEG recording in predicting the tendency to develop epileptic seizures later in life has, however, not been documented. Since very little attention has been paid to the EEG in these children prior to primary surgical intervention the present study was undertaken to clarify changes seen in the EEG of hydrocephalic children before the initial shunting procedures.

Patients and methods

During the years 1966--1984, 175 children with hydrocephalus were shunted at the Department of Pediatrics, University of Oulu, Finland. The unit serves as a referral clinic for pediatric surgery in the northern part of Finland, and virtually all children with this diagnosis in that area are sent to this unit. A total of 1,904 EEG recordings were made on these patients during the follow-up time, all analyzed by the author. The material in this study consists of those 105 children with hydrocephalus, from whom the EEG recordings had been obtained before the initial shunt treatment. The age distribution and the etiology of the patients' hydrocephalus are shown in Table 1.

Prior to shunting the ventriculomegaly was visualized by either pneumoencephalography or ventriculography, carotid-angiography, ultrasound or CT. After 1979, all cases were evaluated using CT before treatment. The intracranial pressure was measured during the initial shunt operation, and it was more than 15 cm H_2O in all cases.

The EEG recordings were done using an 8- or a 16-channel Elema unit. The electrodes were placed according to the international 10--20 system, calibration was 100 µV/10 mm, and the time constant 0.3 s. Referential and bipolar montages were used. Flashing light stimulation and sleep were used as activation methods. Chloral hydrate was occasionally used to induce sleep. The electrodes were silver-silver chloride discs fixed to the scalp with rubberbands, the contact resistance having been reduced to below 5 kOhms by minimal abrasion of the epidermis and saline jelly. The collected data were handled by computer analysis at the University of Oulu, Finland.
Table 1. Age distribution and the etiology of the hydrocephalus in the 105 children studied

<table>
<thead>
<tr>
<th>Etiology of the hydrocephalus</th>
<th>0–28 days (N = 20)</th>
<th>29 days–1 year (N = 45)</th>
<th>1–7 years (N = 33)</th>
<th>&gt; 7 years (N = 7)</th>
<th>Total (N = 105)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perinatal hemorrhage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Infection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Tumor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Malformations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>– Aqueductal stenosis</td>
<td></td>
<td>7</td>
<td>14</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>– Meningomyelocele</td>
<td></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>– Other anomalies (cyst, Dandy-Walker, encephalocele, etc.)</td>
<td>6</td>
<td>11</td>
<td>8</td>
<td>2</td>
<td>27</td>
</tr>
</tbody>
</table>

Dumermuth's criteria for normality/abnormality were used [3]:  
1. Dominant background activity, focal slow waves, focal attenuation, generalized slow wave activity, focal spikes and sharp waves; generalized spike and sharp-wave activities of the EEGs were handled separately as follows:

**Dominant background activity**

Dominant activity in the alert state was classified into four groups [3]:

0: Age-appropriate normal dominant activity [4].
1: Mildly abnormal: dominant activity is greatly restored; slow activity is increased but subdominant.
2: Moderately abnormal: polymorphic theta-delta waves are dominant, but they are superimposed on a basic rhythm. The mean frequency of the basic rhythm is unchanged or more or less reduced.
3: Highly abnormal: diffuse polymorphic delta activity with high amplitude and superimposed theta or alpha waves are seen. There is no organized basic rhythm [3].

**Focal slow waves**

The presence of focal slow waves was defined in the following areas: frontal, central, temporal, parietal, and occipital or anterior and posterior quadrants of the hemispheres. Focal slow waves were considered to be present when there was a localization of polymorphic theta or delta waves with constant localized amplitude maximum and a steep potential gradient [3].

**Focal attenuation**

Focal attenuation was considered to be present when there was a reduction of 50% in amplitude [3].

**Generalized slow-wave activity**

Generalized slow-wave activity was taken to be present when there were high rhythmic slow waves with constant frequency and shape, which appeared clearly distinct from the basic activity [3]. Such waves were observed to be generalized or only posterior.

**Focal spikes and sharp waves**

Focal hypersynchronous activity was defined focal paroxysmal discharges of spikes or sharp waves with or without slow waves. These were also recorded separately in various areas of the hemispheres.

**Generalized spike and sharp-wave activities**

Generalized spike and sharp-wave activity was classified as three different forms: (1) diffusely distributed spikes or sharp waves over both hemispheres or only on one hemisphere; (2) hypersynchrony; (3) hypersynchronous spikes or sharp waves over both hemispheres, including also 2–5 c/s discharges.

In the present study, before a diagnosis of the EEG abnormality was made the normal variability of the EEG was carefully defined, especially with regard to the age and condition of the patient, e.g., sleep transients such as diffuse 3–5 Hz activity during drowsiness with or without posterior accentuation, as well as rhythmic slow posterior activity (2.5–4.5 Hz) were distinguished from actual paroxysmal abnormalities. Slight increases in low-frequency activity, and polyphasic potentials in posterior derivations were also shown as normal variants [11]. In the neonatal period, the following different forms of SeW activity were regarded as normal during sleep: sporadic focal sharp waves, bilaterally synchronous sharp waves, sharp waves or spikes in “trace alternant” episode, and sharp waves or spikes in a beta spindle [6].

**Results**

An entirely normal EEG was seen in only 2 (1.9%) of these 105 patients. The dominant activity was normal in 15 (14%) patients. It was observed only in children younger than 7 years of age (Table 2). Thirteen of these 15 patients with normal dominant activity had one or more other EEG abnormalities (Table 3). In 7 of these 105 patients, the abnormality in the dominant activity was the only observed abnormality, and in 83 cases it was observed in conjunction with many other EEG abnormalities (Table 3). Spike and sharp-wave activity appeared almost entirely with abnormal dominant activity. Only in one case did focal spike and sharp-wave activity appear with normal dominant activity, and generalized spikes and sharp waves were never seen with such a background.

**Generalized slow wave activity** over the hemispheres or posteriorly was seen in 37 (35%) children (Table 2). Slow-wave activity over the hemispheres was more common in patients older than 1 year of age (45% compared with 12%).

**Focal slow waves**, uni- or multifocally, were present in 28 patients (27%), of whom 17 had bilateral focuses (Table 6). Right-sided focuses were seen in 26 recordings, left-sided in 19 recordings (Table 6). A posterior focus was observed in 20 recordings either bilaterally (12 patients) or unilaterally.