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Reversibility of the Chronic Post-Stroke State

K.-H. HOLBACH, M.D., H. WASSMANN, M.D., AND K. L. HOHELÜCHTER, M.D.

SUMMARY Forty patients with cerebral infarction associated with occlusion of the internal carotid artery (ICA) or the middle cerebral artery (MCA) were treated with hyperbaric oxygenation (HO). EEG analyses were performed regularly in order to assess the course of the cerebral lesion. Patients in an early post-stroke stage (III B) and patients in a chronic post-stroke stage (IV) had the changes in EEG analysis and neurological findings distributed evenly between these two groups.

In 27% of the cases, the improvement was considerable, 53% had moderate improvement, and 20% showed no change of condition. The improvement mainly consisted of an increase of alpha-wave and beta-wave activity over the affected brain region. We were able to show this fact clearly by means of the EEG-analysis-system applied. The results show that (a) hyperbaric oxygenation therapy (HOT) has a very favorable influence upon the course of disease, and (b) simultaneous application of HOT and EEG analysis allows for a differentiation between reversible and irreversible post-stroke changes in brain tissue.

Introduction

ELECTROENCEPHALOGRAPHY is helpful in showing changes in patients with cerebral damage. Noting the findings of others we used EEG several years ago to detect the effect of hyperbaric oxygenation (HO) in cases of brain trauma and cerebral infarction. We also applied HO at pressures of 2 to 3 ata* with a length of exposure of at least one hour, and often for a longer period of time.

After we demonstrated by comparative clinico-neurological evaluation and biochemical examinations of the cerebral glucose metabolism that inspiratory oxygen pressure (IOP) above 1.5 ata results in a disturbance of the oxidative glucose, respectively, of the energy metabolism of the injured human brain, we applied HO only at pressures up to 1.5 ata and a length of exposure of approximately 40 minutes. This dosage of oxygen was applied not only once but repeatedly in all cases so that the hyperbaric oxygenation therapy (HOT) consisted of a series of individual HOs.

The electrical brain activity improved in a large number of cases. The conventional EEG examination and evaluation, however, complicated this task because of the rapidly increasing amount of data. We therefore used an automatic EEG-interval-analysis-system which is keyed to the visual evaluation of the EEG curve; the system proceeds by measuring and counting, provides quantifiable and reproducible results, and permits an interpretation of the findings by means of customary EEG concepts.

Methods

Forty patients (24 men and 16 women between the ages of 8 and 68; average age, 46.9 years) were studied; 20 patients with occlusion of the internal carotid artery (ICA) and 20 with an obstruction of the middle cerebral artery (MCA). Twenty of these 40 patients were in the post-stroke stage, III B (stroke without or with only a partial improvement within the first four weeks), and 20 were in the chronic post-stroke stage, IV (permanent neurological symptoms beyond the fourth week). In addition to printing the incidence of events (a) in the respective interval class, the following characteristic measures were determined and printed out (fig. 1). The incidence of sums (b) results by adding the incidence of events of

*An electronic device to determine very accurately short time intervals.

From the Neurochirurgische Universitatsklinik Bonn (Director: Professor Dr. P. Rötgen), D-5300 Bons-Venusberg, West Germany.

*a = atmospheres absolute.
REVERSIBILITY OF THE CHRONIC POST-STROKE STATE/Holbach et al. 297

ORIGINAL EEG

<table>
<thead>
<tr>
<th>INTERVAL</th>
<th>AMPLITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BETA</td>
<td>0  7  27  39  55</td>
</tr>
<tr>
<td>ALPHA</td>
<td>12 35 155 135  70</td>
</tr>
<tr>
<td>THETA</td>
<td>30 26 54 32 21</td>
</tr>
<tr>
<td>DELTA</td>
<td>10 21 18 18  9</td>
</tr>
</tbody>
</table>

RESULTS

If you subject healthy test persons to HO and analyze their EEGs during this time, the following observations are typical. The normal initial EEG of a 24-year-old person shows an alpha-rhythm of 9 to 10 waves per second (fig. 1). The analysis of this derivation reflects this fact clearly in the data protocol and in the pertinent histogram. Here we find the largest number of incidence of events within the alpha-range, i.e., in the interval classes of the 9 to 10 per second waves. The incidence of sums is accordingly the highest within the alpha-range. Since the amplitude information is adjoined to the respective interval class, we also find the highest amplitude values in the 9 to 10 Hz interval class. The EPE value or the mean amplitude value per unit of time for the alpha-range also predominates. By recording the determined EPE values for each of the four wave-ranges and the sum of four EPE values, which constitutes a quantity for the electrical brain activity, during the period of HO, it is possible to show the actual alterations (fig. 2). In the case of the test persons, the alpha activity and beta activity remain more or less unchanged. There are no changes of EPE values for the theta-range and delta-range discernable after 15 minutes of continuous respiration of oxygen under a pressure of 1.5 ata. After 30 minutes under an IOP of 1.5 ata, however, there is a slight decrease of the delta-wave and theta-wave activity observable. Therefore, the sum of the EPE values also slightly decreases. During respiration of oxygen under normal pressure and after changing from oxygen to renewed respiration of air, the theta-wave activity increases again slightly, so that the sum of the EPE value increases again slightly. A comparison between the initial and the final values of the EEG analysis shows no appreciable change. Contrary to this reaction of electrical brain activity, we found, in the case of patients having occlusions of cerebral arteries, the following alterations under HO, as presented by the EEG-analysis findings of three typical cases.

Case I

A 34-year-old woman had had four transient ischemic attacks (TIA) in the form of headaches, vertigo and a slight hemihypesthesia and hemiparesis since 1969. A considerable hemiparesis, hemihypesthesia and an incomplete aphasia suddenly occurred at the beginning of March, 1975. During medical treatment the hemiparesis and the hemi-
hypesthesia improved slightly in the first two weeks after the stroke. From then on the symptomatology remained unchanged. When the patient was admitted to the hospital following her stroke, we found a distinct hemisymptomatology and an incomplete aphasia. The EEG showed a moderate change temporoparietally and the angiogram revealed occlusion of a main branch of the left MCA immediately behind the bifurcation, which caused an extensive temporoparietal avascular region. We began HOT seven and one-half weeks following the onset of stroke.

The EEG analyses, performed prior to the first HO, showed a lower alpha-wave, beta-wave and theta-wave activity over the affected brain region than over the contralateral brain region (fig. 3). After 30 minutes of continuous respiration of oxygen at 1.5 ata, the alpha-wave and beta-wave activity increased distinctly over the affected brain region and only slightly over the contralateral brain region.

This caused a rise in the sum of EPE values and showed an improvement of the electrical brain activity above the affected region, in particular. After reducing the IOP to 1 ata and after changing from oxygen to air respiration, the alpha activity and beta activity slightly decreased again. Comparison between the initial and final EPE values showed an increase of beta-wave activity on both sides. At the end of HO, the value of EPE sums was above the initial value, and the difference was more distinct over the affected brain region. This typical reaction continued during the further course of HOT, so that after the fifteenth HO there was considerable improvement of electrical brain activity. This improvement was on both sides of the brain, and consisted of a conspicuous increase of alpha-wave and beta-wave activity, which was more distinct over the affected brain region. Nevertheless, the electrical brain activity over the affected brain region remained slightly reduced as compared to the contralateral side. This corresponded also to the cliniconeurological process because at the conclusion of HOT there was a latent weakness in the right arm and the dysphasia disappeared. These improvements remained.

Case 2

A 39-year-old woman had occlusion of the right MCA. This led to moderate impairment of consciousness and severe left hemiparesis. Six days later the first HO treatment was given. Corresponding to the neurological abnormality, the EEG analyses performed prior to the first HO showed a distinctly reduced alpha activity and beta activity and a considerable increase of theta-wave and delta-wave activity as compared to the contralateral brain region (fig. 4). After the eighth HO treatment, there was an increase of alpha-wave and beta-wave activity, coinciding with a decrease of theta-wave and delta-wave activity, so that the theta-wave and delta-wave activity practically reached the level of the contralateral side. There was also a distinct increase of alpha and beta activity on the contralateral side. During further HOT, the alpha activity, in particular, continued to increase over the affected and contralateral regions of the brain. At the end of HOT, there was considerable bi-
lateral improvement of electrical brain activity, which was particularly distinct in the affected brain region. There was simultaneous clinical improvement.

Case 3

A 56-year-old patient had occlusion of the right ICA. There were severe left hemiparesis and clouding of consciousness. The patient was treated medically and physically in the hospital. Considerable spasticity developed in the paretic extremities. Eight weeks passed before the beginning of HOT. The conventional EEG-derivation (fig. 5) showed moderately severe general alterations. The EEG registered a basic rhythm consisting primarily of six to seven per second theta waves and of grouped one to three per second delta waves, distinctly accentuated on the right, and scarce beta-wave and alpha-wave activity. Between the right temporal and fronto-precentral regions, there was a focus of dysrhythmia with delta-wave activity.

Before the first HO treatment, the EEG analysis (fig. 6) showed a distinctly reduced total activity with predominant theta activity over the affected side of the brain. The alpha-wave and beta-wave activity were markedly reduced in relation to the delta activity. There were greater alpha activity and beta activity over the contralateral side of the brain. The alpha activity was predominant, but the theta-wave activity also was increased and above the beta-wave activity. After every HO treatment, the alpha-wave and beta-wave activity increased on both sides, so that we could register a distinct increase in these wave regions after the eleventh HO treatment. Whereas the alpha activity just surpassed the theta-wave activity on the side affected, the contralateral side showed that the alpha-wave and beta-wave activity were distinctly more than the decreased theta activity and delta activity. The extent of change in EEG findings, which was based mainly upon the increase of alpha-wave and beta-wave activity, was considerable. The conventional EEG showed an increase of alpha-wave and beta-wave activity and a reduction of slow waves after the conclusion of HOT (fig. 7). After the conclusion of HOT, the hemiparesis improved.

Forty patients with stroke caused by occlusion of cerebral arteries, similar to the cases previously described, were treated and observed. These 40 cases were divided into three groups (table 1). Group 1 (11 patients) showed considerable improvement of electrical brain activity, corresponding to an increase in EPE values of more than 30% of the initial value. Group 2 (21 patients) showed an increase of the electrical brain activity after HOT in relation to the initial EPE values: > 30% in relation to pretreatment value; 10% to 30% in relation to pretreatment value; 0% to 10% in relation to pretreatment value.

### Table 1: Changes of EPE in 40 Stroke Patients Treated With HO

<table>
<thead>
<tr>
<th>Group</th>
<th>Definite increase*</th>
<th>Moderate increase</th>
<th>No change</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11 (27%)</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>21 (53%)</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>8 (20%)</td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

*Patients were divided according to the improvement of the electrical brain activity after HOT in relation to the initial EPE values: > 30% in relation to pretreatment value; 10% to 30% in relation to pretreatment value; 0% to 10% in relation to pretreatment value.
The increased supply of energy is probably the basis for tissue repair and the resumption of functional performance. Differentiating between functional and permanent ischemic alterations of brain tissue is of great importance in the evaluation of the post-stroke stage. Currently, a number of patients, showing little change in neurological status more than four weeks after their stroke, are classified in the chronic post-stroke stage. Nevertheless, the condition of some of these patients showing improved after HOT suggested that surgical reconstruction of arteries might be helpful, while others not subjected to HOT may or may not respond to this treatment. The method described here assists in separating these two important categories. A separate report will describe such experience.

References