Significance of Individual Variability in EEG Response to Electroshock

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The assumption is often tacitly made in studies of nervous system function that the capacity for neurophysiological change is similar for animals or humans in the groups under study. Differences in response are ascribed to different parameters of the stimulus or to differences in the location and extent of lesions, either spontaneous or experimentally produced. Such an assumption may not be warranted, however. Perhaps another factor in the variability of response under these conditions is an individual variability in neurophysiological reactivity or responsiveness. The initial "base-line" may not be similar in all individuals.

The possibility of different inherent patterns of reactivity has been suggested by the studies of the alterations in the EEG during electroshock. We have been impressed by the high degree of variability in such alterations both in their quantitative and qualitative aspects. Although this variability has been described by previous investigators, it has not been stressed sufficiently; nor have possible explanations been advanced or systematically investigated.

The present report concerns a description of the changes in the EEG during electroshock in the Hillside Hospital material. The concept of neurophysiological reactivity is presented and studies that may clarify this problem are suggested.

MATERIAL AND METHODS:

Eighty-nine patients who received electroshock for psychiatric illness were studied. The patients were voluntary admissions to Hillside Hospital and the majority had not received electroshock previously. The diagnostic groups included psychotic depression, manic-depressive psychosis and schizophrenia. The largest group was patients with depression. Ages ranged from 20 to 68 years, with a median of 47 years.

Treatments were given three times weekly, each patient receiving at least 12 treatments. The Medcraft instrument (alternating current) was used for 28 patients and the Reiter instrument (unidirectional current) for 61 patients. Electroencephalograms were taken prior to, at weekly intervals during, and two weeks following the course of treatment. Patients whose pre-treatment EEG was abnormal were specifically excluded from study. Tracings were done on a non-treatment day (from 24 to 36 hours following the previous treatment) with an eight channel Medcraft machine using needle electrodes. Frontal, motor, parietal, occipital, anterior temporal, posterior temporal, vertex and earlobe placements were employed with scalp to scalp and scalp to earlobe combinations.

RESULTS:

I. Delta Activity.

A. Quantitative Differences: The delta activity was analyzed according to the method described by Fink and Kahn (8). The duration of burst activity, the lowest frequency, the average delta index in several leads, the highest amplitude, and the highest percent time delta in one lead were measured. Records were classified as showing a low, middle or high degree of delta activity (Fig. 1) according to criteria previously described (8).

All patients developed delta activity during the course of 12 treatments but differences in the amount of the slow activity and its rate of development were very apparent (Table I). Some patients developed "high delta activity" early in treatment whereas other patients showed only "low" or "middle" changes even after 12 treatments. These latter patients were followed further with serial EEG's. As treatment was continued, a high degree of delta activity did not develop in some of these patients until 20 or more treatments, or until treatments were given on a daily basis. They were resistant to neurophysiologic change. This individual variability in EEG response was independent of the type of electroshock current employed, being present both with alternating and with unidirecticnal current applications.

TABLE I

Degree of Delta Activity in Serial Electroencephalograms during Electroshock

(2-4 records were taken for each patient)

	No. of Records in Each Treatment Period			
EEG Activity	EST 1 - 3	4 - 6	7 - 9	10 - 12
No change	5	1	1	0
Low delta activity	16	37	21	7
Middle delta activity	3	20	22	10
High delta activity	1	28	45	25

B. Qualitative Differences: Although the total amount of delta activity may be similar, records differ as to type, frequency and voltage of delta activity. One prominent qualitative difference is the ratio of irregular delta activity to bursts of slow activity. Nearly all records show burst activity during a course of 12 treatments. In some patients the initial delta change is in the form of bursts which become more frequent, slower and of higher voltage as treatments are continued. The irregular delta activity in such records is much less prominent and usually occurs at faster frequencies. In other patients the reverse occurs. Delta activity appears chiefly in an irregular and scattered form. Although burst activity is also present, it is not conspicuous. In a third group of patients the amounts of irregular delta and bursts are approximately equal (Fig. 2).

These differences in the form that the delta activity assumes is usually constant during the course of treatment. At times, however, burst activity will

become more prominent than the irregular delta only during the latter part of the course of treatment; or burst activity which appears prominent early in treatment may be overshadowed and obscured in later records by a large amount of continuous irregular delta activity.

The slow activity is maximal at the anterior temporal and frontal electrodes and less pronounced at the more posterior electrodes. Often it is asymmetric, being of higher voltage, slower, and in greater amounts at the left anterior temporal and frontal electrodes as compared to the right (Fig. 2). Only rarely is the reverse true, i.e. accentuation on the right side. This asymmetry occurs during treatment both with alternating and with unidirectional currents.

Another type of abnormality, though an infrequent one, is the appearance of rhythmic runs of delta activity which may continue for 10 to 20 seconds (Fig. 2). The regularity of the frequency and voltage of the slow waves in these runs is very striking. These runs are usually infrequent, but may be the most prominent alteration in the record.

In many records the amount of delta activity fluctuates during the tracing. At times, some portions of a record may appear nearly normal, while in other parts of the same record the delta activity may be quite pronounced. This variation is independent of the electrode combinations employed.

II. Spike or Spike-Wave Activity:

A large number of records show single spike activity of low, moderate or high voltage. Most often such spikes are slower and not as prominent as

those present in patients with seizure disorders. A small number of records show spike-wave activity. This is usually at irregular, mixed frequencies and, again, does not resemble the regular rhythmic bursts commonly seen in patients with seizure disorders (Fig. 2).

III. Alpha Activity:

The alpha activity shows changes both in amount and frequency. As the amount of delta activity increases the amount of alpha activity usually decreases. Changes in frequency occur but are not pronounced. The frequency will be slowed by 1-2 cps but at times will remain the same as in the pre-ECT tracing. In a small number of patients the amount and voltage of alpha activity increases during treatment. This change persists during the post-treatment period after the slow-wave activity subsides (Fig. 3).

IV. Beta Activity:

The fact that many sedatives, particularly barbiturates, induce fast activity in the EEG and the difficulty in controlling the administration of these drugs in this population studied makes it difficult to evaluate changes during the course of treatment. In most instances changes in fast activity are minimal. The most frequent change, when present, is a decrease in the activity.

Discussion:

The problem being raised is that of the individual variability in the type and degree of EEG alteration during electroshock therapy. As described, this is manifested in: 1) the amount of slow-wave activity and its rate of development; 2) qualitative differences in the slow-wave activity (amount of burst activity vs irregular delta activity, symmetry, fluctuating appearance of slow activity, runs of rhythmic slow activity); 3) presence of spike or spike-wave activity; and 4) changes in alpha and beta activity.

Previous investigations (2, 4, 5, 10, 11, 12, 14, 17, 18, 19, 20, 25) have stressed possible correlations with age, sex, frequency of treatment, type of current employed, psychiatric diagnosis, and clinical change. Increasing the frequency of treatment, for example, will increase the degree of alteration in the EEG. However, when patients of similar sex, age and psychiatric diagnosis are given treatments at the same frequency with the same type of electroshock current, variability in the rate of development of changes in the EEG and their type and degree are still very prominent.

One explanation for this variability might be the distribution of the electroshock current in the brain. Perhaps minor differences in the resistance of the skull, in the distribution of blood vessels and their permeability or in the arrangement of nerve tracts create differences in the pathways taken by the current. Under such circumstances, different portions of the brain may receive more or less current in one patient as compared to another. Differences in the type of electrical activity generated by these variously affected areas might account for variability in the EEG.

Available studies employing direct intracerebral measurements indicate considerable diffusion of current throughout the brain (6, 9, 16, 21).

However, a concentration of current anteriorly and along large neuronal pathways, such as the corpus callosum, has been demonstrated. No further information is available as to amounts of current received by more specific cerebral areas.

Due to the high resistance of the skull only a small portion of the applied current actually reaches the brain. The amount of current entering different portions of the brain is said to be determined by the resistance of the skull overlying these areas; the anterior concentration of current being the result of the thinness of the temporal bone with its consequent lower resistance as compared to other parts of the skull (9, 21).

Several considerations, however, indicate that individual differences in these factors of resistance and amount of current reaching different areas of the brain are of minor, if any, importance in the EEG response during electroshock. It is the occurrence of the generalized seizure per se, rather than the passage of electricity, which is the primary factor. During a course of grand-mal therapy induced by non-electrical means such as metrazol, EEG changes occur which are similar, in general, to those seen with electroshock (13, 14). Diffuse slow-wave activity, accentuated anteriorly, and spike or spike-wave activity are described. The amount of slow-wave activity increases during treatment but shows individual variability unrelated to the number of treatments. Another observation is that electro-shock therapy which induces petit-mal (7, 18) or focal (3) seizures rather than grand-mal, does not produce the characteristic build-up of slow-wave activity. In addition, there is no increase in the degree of delta activity in our patients in whom grand-mal therapy is given with high suprathreshold stimuli as compared to those in whom threshold stimuli are used.

Factors of current cannot be entirely dismissed, however. Even with grand mal therapy, the type of current employed may influence the EEG change. We have confirmed a previous study (20) showing that the rate of increase of delta activity is slower in therapy with unidirectional current than in that with alternating current. Similarly, brief stimulus therapy is said to produce smaller degrees of alteration in the EEG as compared to alternating current therapy (15).

The other theory to be considered in explaining the variability in EEG responsiveness, and the one which is probably more determinant, involves inherent differences in neurophysiological reactivity. By this is meant both the quantitative and qualitative aspects of the inherent capacity of the nervous system to respond to stimuli or injury. Not only the degree of response, but also the type of response, may have these determinants. The type and degree of EEG abnormalities developed during electroshock therapy appear to be the reflection of such inherent individual differences in neurophysiological reactivity.

Several types of investigation may serve to test this hypothesis. Methods other than electroshock known to produce EEG alterations could be applied prior to treatment. These might include lowering the blood sugar by parenteral insulin, intravenous administration of convulsants such as metrazol or Megimide, photic stimulation, or the intravenous administration of drugs such as barbiturate. In addition, perhaps the actual electroshock seizure threshold or the pattern of severity of the seizures may be a measure of nervous system responsiveness. Data from such investigations could be correlated with the degree and types of EEG change during electro-shock. In this manner it might be possible to demonstrate different patterns

of neurophysiological reactivity and classify individuals accordingly.

Such studies may not only help in understanding the variability in the EEG alterations during electroshock but would have wider application to other problems in clinical electroencephalography and neurology. For example, the basis for the development of spontaneous seizures secondary to traumatic, vascular, or neoplastic lesions of the nervous system is not known. Patients with lesions comparable in type, size and location may or may not develop seizures. As previously described, some subjects show spike or spike-wave activity during electroshock. This suggests an inherent difference in the capacity to develop clinical seizures or EEG seizure activity following "injury" to the nervous system, whether the injury is spontaneous or induced. Differences in this capacity may be reflected in varying patterns of neurophysiological reactivity.

Differences in neurophysiological reactivity may also be manifested in the pre-treatment EEG. Patients in whom the pre-treatment record is abnormal (11), "instabile" (22), or shows a predominant alpha rhythm (5) are said to develop the greatest alteration in the EEG during electroshock. Other investigators have not confirmed these observations (2, 23). Actually, such correlations depend on the method of analysis of the pre-treatment record employed and the criteria used for "abnormality." Further investigation of this relationship is necessary.

Suggesting that neurophysiological reactivity is an inherent process does not imply that a physiological basis does not exist or cannot be investigated. This may reside in the central nervous system itself, consisting of individual differences in neurochemical systems or in the permeability of cells or blood vessels; or it may be outside the nervous system. Individual

differences in hormonal or other humoral substances produced during the stress of electroshock may serve to "sensitize" or "desensitize" the cerebrum with regard to developing different amounts and types of electrical activity. That such factors may be operative is suggested by the following studies. Trypan red injected intraperitoneally in cats before a course of electroshock decreased the permeability of the blood-brain barrier and reduced the degree of EEG changes as compared to control animals (1). Atropine and scopolamine adminstered during a course of electroshock in man blocked the development of the usual slow-wave activity (24).

Electroshock therapy affords an excellent opportunity for the experimental investigation of the problem of an inherent neurophysiological reactivity. One is able to apply studies directly to man, rather than animals. The stimulus to the central nervous system can be standardized and the degree of neurophysiological change controlled, within limits, by changing different parameters. Tests of EEG responsivity can be given before such changes are induced as well as during and after treatment. Re-study of patients is often possible when subsequent courses of treatment are necessary.

Summary:

1. Individual differences, both quantitative and qualitative, in the EEG changes during a course of electroshock treatment in 89 patients are described.

2. These differences are pronounced and are not explainable by age, sex, type of shock current, frequency of treatment, psychiatric diagnosis, or clinical change.

3. An inherent capacity for neurophysiological change that has both quantitative and qualitative aspects may be the primary determinant of these differences.

4. Variation in skull resistance and in the amount of current reaching the brain appear to be minor factors.

5. Investigations that might serve to test the hypothesis presented are described. Such studies may lead eventually to a classification of individuals as to different patterns of neurophysiological reactivity and clarify other problems in clinical neurology and electroencephalography.

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