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Relation of Electroencephalographic Delta Activity to Behavioral Response in Electroshock

Quantitative Serial Studies

MAX FINK, M.D., and ROBERT L. KAHN, Ph.D., Glen Oaks, N. Y.

Recent theories of electroshock therapy [1-3] have emphasized the role of neurophysiologic changes as the basis for the therapeutic action of electroshock. Consistent with these theories, we have observed a relation between changes in certain measures of brain function and behavioral response. We have noted that evaluations of clinical improvement following electroshock are related to changes in orientation and confabulation after intravenous amobarbital,[4] learning and recall,[5] and syntactical aspects of language.[6]

In view of these observations, it could be expected that electroencephalographic studies would show a similar relationship. Numerous observers have reported consistent changes in the electroencephalogram after electrically induced convulsions. There is diffuse slowing with increased voltage and dysrhythmic activity.[7-12] Fast activity decreases, both in voltage and in percent time,[13] and in patients who are intensively treated there is a slowing of persistent alpha frequencies.[14] The degree, duration, and extent of delta activity are directly related to the frequency and number of grand mal convulsions.[8-14] Such activity is usually symmetric and appears maximal in anterior leads, and the electroencephalographic effects usually disappear in the four to eight weeks following the last treatment.[8,9]

In contrast to the consistency of these observations, studies of the relationship between the electroencephalographic and the clinical changes show conflicting results. Chusid and Pacella,[15] after an extensive review of the literature, concluded that the number of treatments rather than the degree of induced delta activity, was the primary factor related to a favorable therapeutic response. On the other hand, Hoagland et al.[16] reported a relation between changes in the percent time fast activity (more than 13 cps) and independent clinical ratings of behavioral change. Roth [2] similarly reported a relationship between changes in the clinical state and alterations in the delta response induced by intravenous thiopental sodium.

The divergent observations reflect variations in methodology. The present study is an attempt to apply quantitative methods of analysis of serial electroencephalographic records to this problem. The purpose of this study is to determine (1) the relation of changes in electroencephalographic delta activity to the behavioral response in electroshock, and (2) if a relationship does exist, the significance it may have for an understanding of the electroshock process.

Subjects and Method

1. In the initial series, 24 consecutive patients referred for electroshock were studied. Electroencephalograms were obtained prior to treatment and at weekly intervals during and after treatment, using an eight-channel Medcraft electroencephalograph and needle electrodes. Recording was bipolar, and hyperventilation activation was utilized

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during each recording. During the treatment period, records were taken on the day following a treatment, generally 25 to 31 hours later.

Grand mal electroshock therapy was administered by staff psychiatrists, using a Reiter C-47 electrostimulator. Treatment schedules were three times a week, and the number of treatments varied from 9 to 33. As patients showed a clinical response, the psychiatrist tended to give fewer and more widely spaced treatments. There were 15 women and 9 men in the series, and the ages ranged from 24 to 68, with a median of 47 years.

Evaluation of EEG Records.—A total of 160 records were obtained on these subjects. Following the suggestion of Strauss,[17] the delta index was determined for three lead combinations (frontal-parietal, anterior temporal-vertex, and parietal-ear lobe) for 60 seconds of recording for each lead. The delta index is defined as the percent time occupied by waves of 7 cps or slower.

The run of each selected lead combination was scanned, and 180 cm. (60 seconds) of recording that was artifact-free was noted. An additive map measure was run along the base of all waves of 7 cps or slower, determining the number of centimeters occupied by such slow activity. The ratio of this figure to 180 was the delta index of that combination.

After these measurements were made, the record was scanned for the slowest frequency clearly identified at least twice in these selected lead combinations, and for the highest voltage of these slow waves. The total record was also scanned for burst activity. The duration of burst activity, the regularity (modulation) of the waves in the burst, and average voltage were noted.

In the final estimates of degree of delta activity, the average delta index for the three lead combinations, the highest delta index in any one lead, the slowest frequency, highest delta voltage, and duration of longest period of burst activity were listed for each record. The 160 records were arranged in sequence for each index and the percentile rank determined. The ranks were added and the records then arranged in rank order according to this score. On the basis that the higher score reflected a greater degree of delta activity, the upper third of the records was classified as "high-degree delta"; the middle third, as "moderate-degree delta," and the lowest third, as "low-degree delta." An example of each is shown in Figures 1, 2, and 3, respectively.

High-degree delta records were characterized by an average delta index of at least 18%, a delta index of 21% or more in one of the three measured leads, a slowest frequency of less than 3¾ cps, a highest delta voltage of more than 100μv, and a burst duration of at least two and a half seconds.

Low-degree delta records were characterized by an average delta index of less than 2%, a highest delta index in one lead of 3% or less, frequencies no slower than 5½ cps, voltages of less than 60μv, and burst duration of less than one-half second.

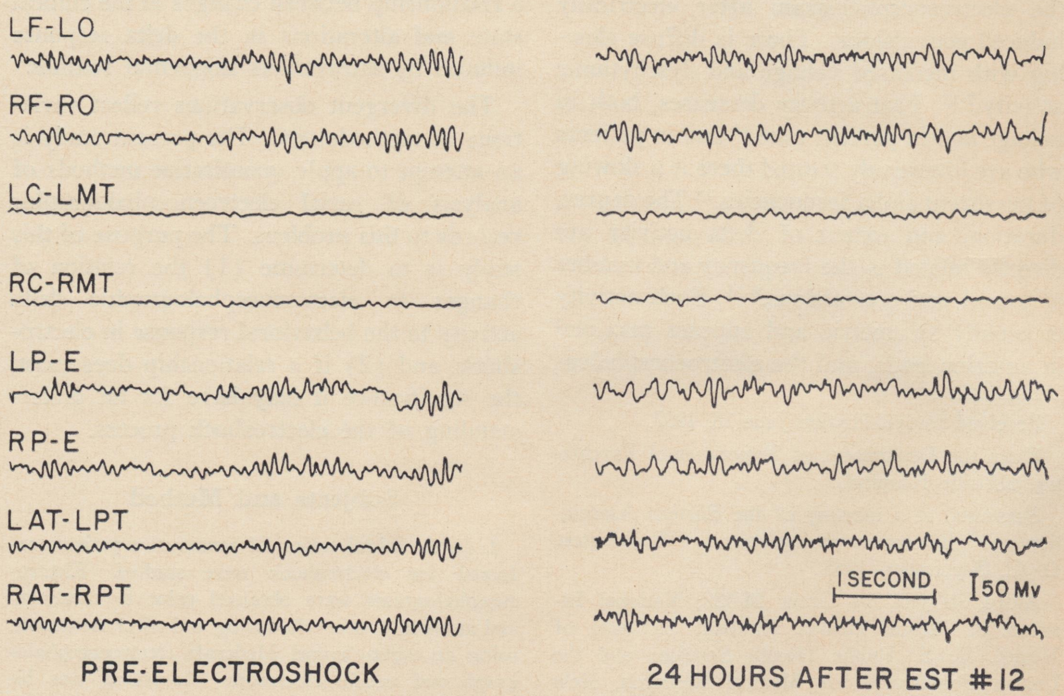
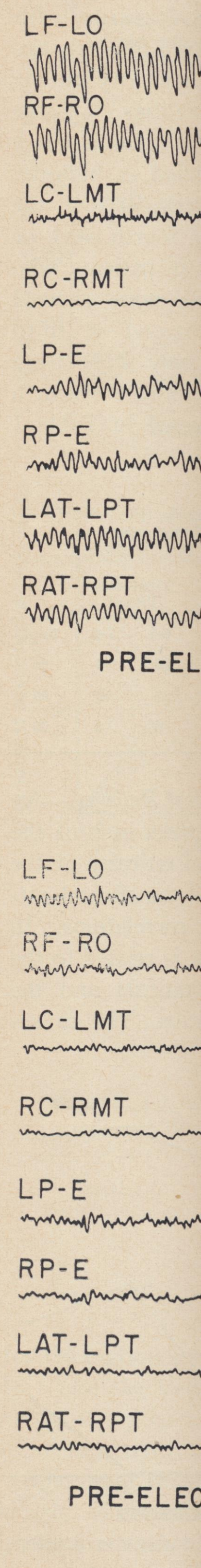


Fig. 1.—Low-degree delta activity.



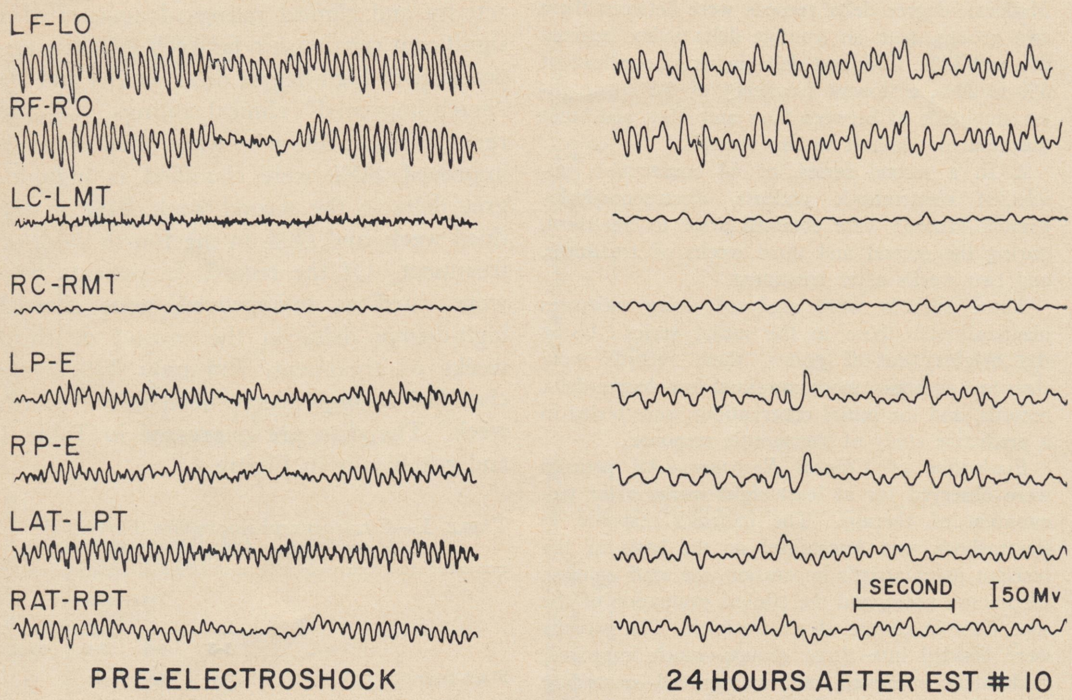


Fig. 2.—Moderate-degree delta activity.

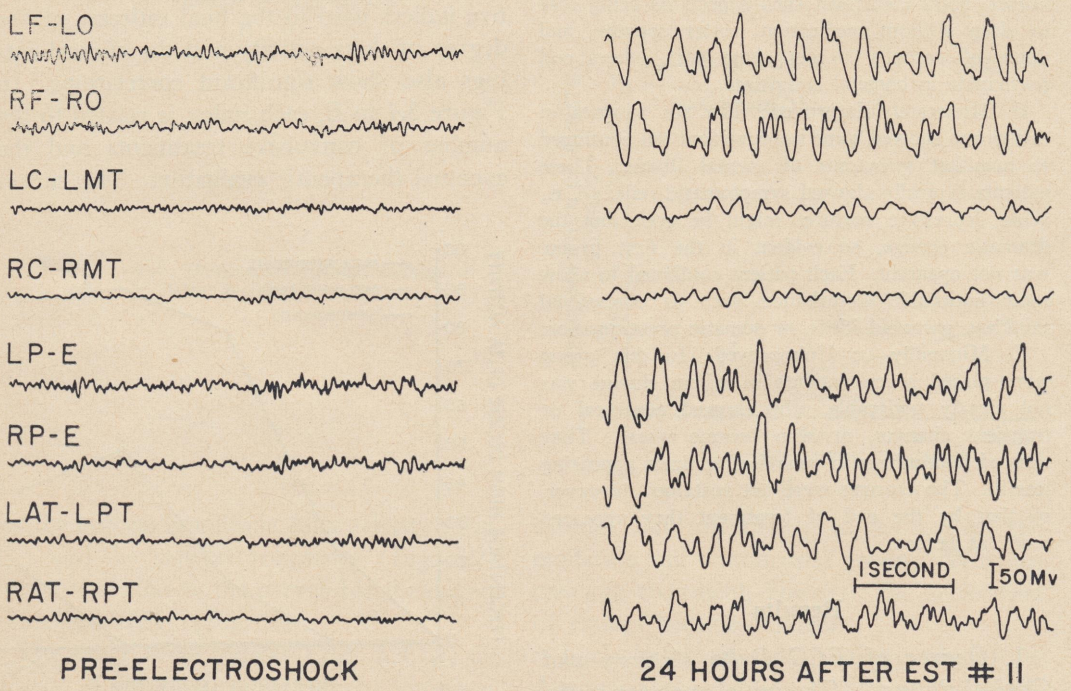


Fig. 3.—High-degree delta activity.

Moderate-degree delta records were between these two groups, with an average delta index between 2% and 18%, a highest delta index in one lead of 3% to 20%, a slowest frequency of 4-5 cps, highest amplitude of between 60μv and 90μv, and burst duration of one-half to two seconds.

2. In a second series, of 54 consecutive, unselected electroshock patients, electroencephalographic records were obtained prior to treatment, during the second and third weeks of treatment, and two weeks after treatment.

These records were analyzed using measures identical with those in the initial series. Using the original cut-off points, these records were classified as high-, moderate-, and low-degree-delta records, and the initial observations were tested in a predictive study of therapeutic response.

Evaluation of Clinical Response.—All patients were observed for at least eight weeks after termination of therapy. The patient's response to electroshock was determined on the basis of the resident psychiatrist's impression, the staff opinion, the nurse's notes, and the clinical evaluation of the supervisor in charge of electroshock. The patients were divided into three groups—much improved, moderately improved, and unimproved—according to the following criteria:

A. Much Improved: The 11 cases in this group were regarded as showing recovery or marked improvement. These patients no longer presented the symptoms which brought them into the hospital; their doctors felt they were better, and the nurses' notes confirmed such aspects as being able to sleep without medication, better appetite, and improved capacity to get along with others and participate in hospital activities.

B. Moderately Improved: The six patients in this group showed some improvement but continued to manifest symptoms of mental illness. These patients typically showed symptomatic relief; i. e., acute depressive features might be gone, but the dramatic change, so evident in the first group, was not apparent. Each patient continued to show some noticeable disturbance, such as obsessional thinking, paranoid ideas, or somatic preoccupation.

C. Minimally or Unimproved: In this group were placed seven patients in whom change was not clearly noticeable, who showed equivocal or transient changes, or who became worse. They showed fluctuations in behavior, at times appearing less ill. The changes were not sustained, however, so that by the end of treatment they appeared much as before.

Results

1. *Degree of EEG Delta Activity and Clinical Ratings.*—The initial analyses of the relation between the degree of induced delta activity and clinical ratings demonstrated a significant relationship between the early appearance of high-degree delta activity and the "much-improved" clinical ratings. Of the records in patients who were rated as much improved, 80% were classified as high-degree delta in the second week, 91% in the third week, and 88% in the fourth week of treatment. Of the records in patients who were rated as unimproved, none showed high-degree delta in the second or third weeks of treatment, and only 20% were classified as high-degree delta in the fourth week. The data are expressed in Table 1 and graphically in Figure 4.

Table 1.—*Electroencephalographic Percentage of High-Degree Delta Records*

	Treatment Period			
	1–3	4–6	7–9	10–12
Much improved (11)	25	80	91	88
Moderately improved (6)	0	16	50	40
Unimproved (7)	0	0	0	20

2. *Delta Indices and Clinical Ratings.*—An analysis of the relation between each of the five indices used in the final estimate of the degree of delta activity and the clinical ratings also show significant correlations. In Figure 5*A* to *E*, each index is related to the number of convulsive treatments and the eventual therapeutic evaluation. The curves

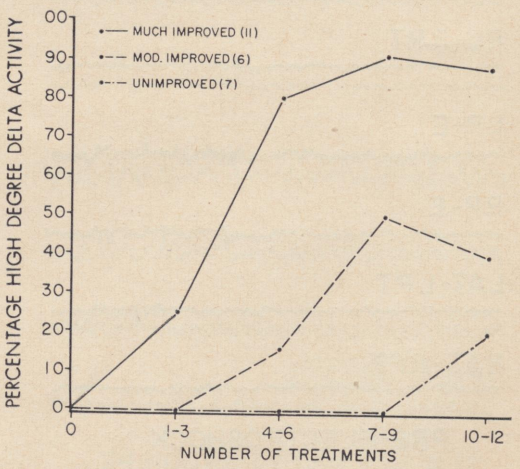
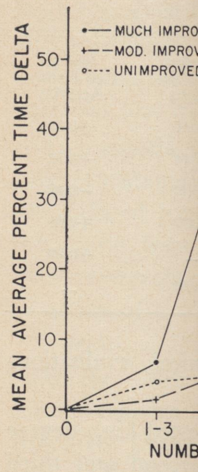


Fig. 4.—Relation of clinical ratings to development of high-degree delta activity.



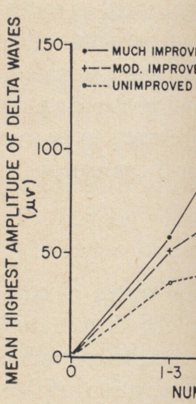


Fig. 5.—*A-E*, r
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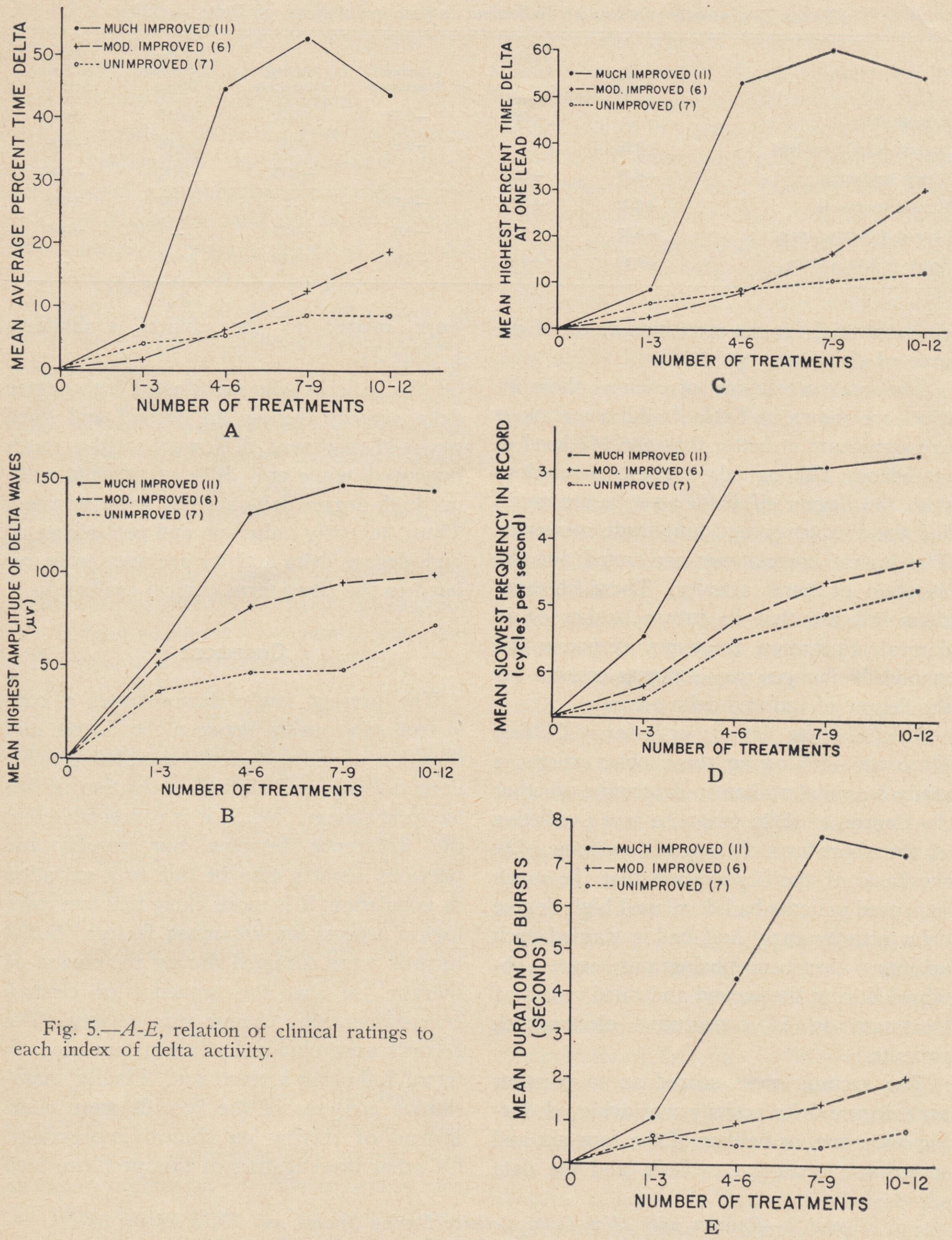

Fig. 5.—*A-E*, relation of clinical ratings to each index of delta activity.

for the highest-amplitude delta activity (Fig. 5*C*) and the slowest frequency (Fig. 5*D*) are most similar to the curves for the degree of delta activity (Fig. 4).

The other three indices (Fig. 5*A, B, C*) clearly differentiate the much improved group from the patients with the other two ratings, but fail clearly to distinguish the moderate and unimproved groups. With increasing treatment, however, the separation of classes becomes clearer.

Each index of delta activity, therefore, demonstrates a relation to the eventual short-term clinical rating which is much like that

TABLE 2.—*Intercorrelations of Individual Indices and Degree of Delta Activity*

	Average Delta	Highest Delta in One Lead	Lowest Frequency	Highest Amplitude	Longest Duration Bursts	Degree of Delta Activity
Average delta	--	+0.98	—0.79	+0.72	+0.67	+0.80
Highest delta in one lead	+0.98	--	—0.67	+0.72	+0.68	+0.84
Lowest frequency	—0.79	—0.67	--	—0.78	—0.47	—0.90
Highest amplitude	+0.72	+0.72	—0.78	--	+0.57	+0.88
Longest duration bursts	+0.67	+0.68	—0.47	+0.57	--	+0.63
Degree of delta activity	+0.80	+0.84	—0.90	+0.88	+0.63	--

demonstrated for the combined index of degree of delta activity.

The intercorrelations of each of these indices are shown in Table 2. All correlations are significant at better than the 1% level of confidence, although the highest correlations with the degree of delta activity are noted for the frequency and amplitude measures. The lowest correlations are noted for the duration of burst activity. These observations indicate that in future studies or in clinical application frequency response and amplitude changes may serve as criteria for the degree of induced delta activity.

3. *EEG Delta Activity as Index of Clinical Outcome.*—Following these observations, a study was undertaken to determine whether the degree of delta response was predictive of the short-term therapeutic outcome. On the basis of the observation that the much improved patients had developed high-degree delta activity early and had sustained such activity, electroencephalograms were obtained during the second and third weeks of treatment on 54 consecutive electroshock patients.

The records were scored as to whether high-degree delta activity was achieved during both, one, or neither of the four-six and seven-nine treatment periods, and the data were related to the clinical evaluations (Table 3).

Of the patients who manifested high-degree delta activity during the second and third weeks of treatment, 67% were rated as much improved, while only 30% of patients without high-degree delta activity were so rated. Thus, the early induction and persistence of high-degree delta activity are seen to be related to the short-term clinical evaluation.

Comment

The present study demonstrates a consistent relationship between the degree and duration of induced electroencephalographic delta activity and clinical evaluation of behavioral change. While it is conceivable that the difference between our results and previous reports may be due to a variation in population, it is more likely that methodological aspects are important factors. Serial records were obtained during the course of therapy, so that the sequence of electroencephalographic change was evident. The records were obtained at a constant time interval following a treatment. Finally, quantitative analyses of the records were made instead of relying on clinical impressions. Of other investigators of this problem, both

TABLE 3.—*Patients with High-Delta Activity During Second and Third Weeks of Treatment* *

EEG Delta	Clinical Rating: Much Improved	Moderately Improved	Unimproved
Both high (18)	12 (67%)	4 (22%)	2 (11%)
One high (16)	4 (25%)	8 (50%)	4 (25%)
None high (20)	6 (30%)	7 (35%)	7 (35%)

* Significant at the 2% level of confidence.

Roth [2] and Hoagland et al.,[16] who carried out systematic EEG analyses, were also able to demonstrate a relationship between EEG variables and behavioral changes.

Two aspects of these observations warrant further elaboration: the relation and role of the induced neurophysiologic change to the behavioral response, and the significance of these observations for a theory of the mode of action of electroshock therapy.

1. *Relation of Neurophysiologic Change to Behavior.*—Behavioral change is a consistent accompaniment of alteration in cerebral function. Changes in mood, language, attitude, judgment, thought process, perception, and insight attend changes in cerebral function, from whatever cause, and have been extensively documented in the neurologic literature.

In this study, electroshock has been shown consistently to alter the electroencephalogram in a fashion which we have come to associate with states of altered cerebral function. The studies of Davis and Davis,[18] Ostow and Strauss,[19] Ostow and Ostow,[20] and Jung [21] have affirmed the significance of diffuse delta activity as an index of altered brain function. Symmetric, dysrhythmic delta activity has been interpreted as evidence of dysfunction of midline hypothalamic centers—the centrencephalic system.[19] Such activity is also indicative of an alteration in the state of consciousness, more marked alteration being directly related to the duration, amplitude, and frequency of the slow-wave activity.[18,21,22] The demonstrated relationship between induced delta activity and behavioral response after electroshock, therefore, permits the conclusion that changes in the centrencephalic system with attendant alteration in consciousness are the physiologic basis of the electroshock process.* A similar conclusion was presented by Roth [23] on the basis of his studies of the effect of thiopental on electroencephalographic delta activity.

Another example of the relation of the electroencephalographic delta activity to behavior is seen in reports of epileptic patients. Landolt [28,29] describes a young epileptic who was ordinarily pleasant, friendly, and cooperative for his clinic visits. At these times, records were consistently dsyrhythmic. On one occasion he was surly, irritable, and withdrawn, and his EEG was without delta activity. On the subsequent visit, the EEG was again dysrhythmic, and a behavioral "improvement" was noted. Similar observations have been reported by Brockman et al.[30] and Fabing.[31]

In a previous study [4] we had applied the amobarbital test for brain disease [32] in a serial fashion to this group of patients and reported a relationship between changes in this index of cerebral function and behavioral change. Were other tests of cerebral function to be applied in a similar fashion, it is anticipated that these, too, would demonstrate consistent changes during treatment and a relation to behavioral response, within the limits of the sensitivity of the test to reflect changes in cerebral function. In this context, electroshock may be said to be a method of inducing a state of altered brain function for extended periods, in order to achieve changes in behavior.

From this point of view, the development of a significant degree of electroencephalographic delta activity may be a readily determined guide in the rational management of electroshock therapy. In these studies we have examined various delta indices and/or the intercorrelations and have noted that the amplitude and the frequency of the induced slow waves are the best guide to the degree of delta activity. In patients in whom the behavioral response to electroshock is inconsistent with the therapeutic expectation, examination of the electroencephalogram may provide a criterion for clarification. If the induced slow-wave activity is faster than 4 cps and lower than $100 \mu v$ in anterior temporal-ear lobe or anterior temporal-frontal lead combinations, then there is

* The biochemical substrate of this process has received limited study. Emphasis has been placed on acetylcholine-cholinesterase change,[24,25] alteration in blood-brain barrier,[3] and changes in ionic and protein equilibria [26,27] by different investigators, without definitive conclusions.

presumptive evidence of inadequate electroshock therapy. When frequencies less than 3½ cps and voltages higher than $100\mu v$ are maintained for a number of weeks, the assumption may be made that an adequate degree of altered brain function had been induced and that other factors (environmental, personality, pathophysiologic) were operating to preclude a favorable behavioral response to electroshock. A similar application can be made for amobarbital tests [4] or syntactic language after intravenous amobarbital.[6]

2. *Theory of Electroshock Action.*—These studies of the electroshock process have demonstrated that alteration in brain function is induced early and is sustained in patients in whom the greatest degree of behavioral change is noted. We have emphasized high-degree EEG delta activity and positive amobarbital tests as indices of altered cerebral function, with the knowledge that other indices of altered brain function, applied in the same serial fashion, may also show significant alterations and a relation to behavioral change.

We have been impressed that the ratings of improvement are value judgments of the behavioral response. All patients in whom cerebral changes are induced by electroshock manifest changes in behavior. The range of behavioral patterns induced under these conditions is wide. Only certain patterns are evaluated as improved, however, while others are regarded as "unimproved." "Improvement" is a special case of behavioral response, being a subjective evaluation on the part of the observer that the patient is "better." Electroshock does not induce "improvement"; it induces a milieu of cerebral activity in which behavior is different than before electroshock. To the extent that the induced behavior in depressed patients is perceived as less complaining, depressed, agitated, or anxious, or in schizophrenic patients as less delusional, hallucinatory, or excited, the patient is evaluated as "improved." When behavior, however, is perceived as anxious, agitated, paranoid, complaining, or withdrawn, it is evaluated as "unimproved." The particular type of behavioral pattern induced by electroshock is dependent on a number of factors, such as personality.[33]

Another aspect of the rating of improvement is the environmental response to the induced behavior. The modification of mutism, withdrawal, and negativism to excitement, overactivity, and irritability may be considered a positive movement by the therapist but a disorganization by the ward physician or family. The goals of the therapist and the family, and their expectations and tolerances, are significant factors in the behavioral response of the patient to therapy, and, also, in the ratings of improvement.

These same factors are significant in the duration of the electroshock effect. The induced change in cerebral function persists for only two to eight weeks following even intensive courses of therapy. In many cases, the behavioral response is limited to this period of altered brain physiology. When induced changes in behavior are not adaptive in the milieu of the patient, the behavior reverts to pretreatment patterns. In other instances, the induced behavior is adaptive to the environment, and, we assume, sustained thereafter not by the initial change in brain function but by the newly developed interaction of the subject with environment. That this is indeed true is seen by the frequent successful adaptation of the patient to the hospital milieu after electroshock, only to have a recurrence of symptoms when discharge planning is discussed or discharge is consummated. Altered brain function provides the physiologic milieu in which there is an altered interaction with the environment—the doctor, family, or society.

These observations lead to the conclusion that electroshock therapy is a nonspecific induction of persistent states of altered cerebral function. Such altered cerebral function provides the physiologic milieu for an alteration of the organism's adaptive interpersonal behavior. Changes are induced in perception, language, mood, recall, and judgment which constitute a mode of

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A similar view of the electroshock process was initially expressed by Weinstein, Linn, and Kahn,[1] who emphasized the interrelationship of neurophysiologic changes and behavioral response. This description of the electroshock process is also consistent with the observations of Ulett et al.,[34] Roth,[2] and Aird et al.[3]

The neurophysiologic-adaptive interpretation of electroshock provides an operational definition of the process, which has promise of further elaboration and observation. Such a hypothesis also has application to an understanding of therapeutic process in insulin coma therapy, lobotomy, and tranquilizing agents.

Summary and Conclusions

Serial electroencephalograms obtained at weekly intervals in 24 consecutive patients referred for electroshock were quantitatively analyzed for the degree of delta activity.

A significant relationship was found between the degree and duration of induced delta activity and the clinical evaluation of behavioral change. The results were confirmed in a predictive study in an additional 54 patients.

Differences between these results and those obtained by others are explained in terms of differences in methodology.

A neurophysiologic-adaptive interpretation of the electroshock process is presented. It is concluded that electroshock is the nonspecific induction of persistent states of altered cerebral function, providing the physiologic milieu in which changes in adaptive interpersonal behavior occur.

Improvement after electroshock is seen as a special case of behavioral response under these conditions. The rating is an evaluation by an observer depending on numerous factors, including the type of adaptation, the goal and expectation of the observer (therapist, family, or administrator), and the setting in which the behavior occurs.

Mrs. Helen Donovan, Miss Gayle Wankel, and Mrs. Hannah Mosquera gave technical assistance in this study.

Hillside Hospital.

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In view of these observations it could be expected that electroencephalographic studies would show a similar relationship. Numerous observers have reported consistent changes in the electroencephalogram after electrically induced convulsions. There is diffuse slowing with increased voltage and dysrhythmic activity (7 - 12). Fast activity decreases, both in voltage and in percent-time (13), and in patients who are intensively treated, there is a slowing of persistent alpha frequencies (14). The degree, duration and extent of delta activity is directly related to the frequency and number of grand mal convulsions (8 - 14). Such activity is usually symmetric, appears maximal in anterior leads, and the electroencephalographic effects usually disappear in the 4-8 weeks following the last treatment (8, 9).

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In the final estimates of degree of delta activity, the average delta index for the 3 lead combinations, the highest delta index in any one lead, the slowest frequency, highest delta voltage and duration of longest period of burst activity were listed for each record. The 160 records were arranged in sequence for each index and the percentile rank determined. The ranks were added and the records then arranged in rank order according to this score. On the basis that the higher score reflected a greater degree of delta activity, the upper third of the records were classified as "high degree delta," the middle third as "moderate degree delta" and the lowest third as "low degree delta."

High degree delta records were characterized by an average delta index of at least 18%; a delta index of 21% or more in one of the three measured leads; slowest frequency of less than 3 3/4 cps; highest delta voltage more than 100 microvolts; and a burst duration of at least 2 1/2 seconds.

Low degree delta records were characterized by an average delta index of less than 2%; highest delta index in one lead of 3% or less; frequencies no slower than 5 1/2 cps; voltages less than 60 microvolts; and burst duration less than 1/2 second. Moderate degree delta records were between these two groups with an average delta index between 2% and 18%; highest delta index in one lead of 3 to 20%; slowest frequency of 4-5 cps; highest amplitude between 60-90 microvolts; and burst duration of 1/2 to 2 seconds.

b) In a second series of fifty-four consecutive, unselected electro-

shock patients, electroencephalographic records were obtained prior to treatment, during the second and third weeks of treatment, and two weeks after treatment.

These records were analyzed using the identical measures as in the initial series. Using the original cut-off points, these records were classified into high, moderate and low degree delta records, and the initial observations were tested in a predictive study of therapeutic response.

Evaluation of Clinical Response: All patients were observed for at least eight weeks after termination of therapy. The patient's response to electroshock was determined on the basis of the resident psychiatrist's impression, the staff opinion, the nurse's notes and the clinical evaluation of the supervisor in charge of electroshock. The patients were divided into three groups - much improved, moderately improved and unimproved - according to the following criteria.

A. Much Improved: The 11 cases in this group were regarded as showing recovery or marked improvement. These patients no longer showed the symptoms which brought them into the hospital; their doctors felt they were better; and the nurses' notes confirmed such aspects as being able to sleep without medication, better appetite, and improved capacity to get along with others and participate in hospital activities.

B. Moderately Improved: The six patients in this group showed some improvement but continued to manifest symptoms of mental illness. These patients typically showed symptomatic relief, i.e. acute depressive features might be gone, but the dramatic change so evident in the first group was not apparent. Each patient continued to show some noticeable disturbance such

as obsessional thinking, paranoid ideas, or somatic preoccupation.

C. Minimally or Unimproved: In this group were placed seven patients in whom change was not clearly noticeable, who showed equivocal or transient changes, or who became worse. They showed fluctuations in behavior, at times appearing less ill. The changes were not sustained, however, so that by the end of treatment, they appeared much as before.

RESULTS:

1. Degree of EEG Delta Activity and Clinical Ratings:

The initial analyses of the relation between the degree of induced delta activity and clinical ratings demonstrated a significant relationship between the early appearance of high degree delta activity and the "much improved" clinical ratings. Of the records in patients who were rated as much improved, 80% were classified as high degree delta in the second week; 91% in the third week and 88% in the fourth week of treatment. Of the records in patients who were rated as unimproved, none were high degree delta in the second or third weeks of treatment, and only 20% were high degree delta in the fourth week. The data is expressed in Table I, and graphically in Figure 4.

TABLE I

EEG - % High Degree Delta Records

Treatment period	1-3	4-6	7-9	10-12
Much Improved (11)	25	80	91	88
Moderately Improved (6)	0	16	50	40
Unimproved (7)	0	0	0	20

2. Delta Indices and Clinical Ratings:

An analysis of the relation between each of the five indices used in the final estimate of the degree of delta activity and the clinical ratings also show significant correlations. In figures 5A to 5E, each index is related to the number of convulsive treatments and the eventual therapeutic evaluation. The curves for the highest amplitude delta (figure 5C) and the slowest frequency (figure 5D) are most similar to the curves for the degree of delta activity (figure 4).

The other three indices (Figures 5A, B, C) clearly differentiate the much improved group from the patients in the other two ratings, but fail to clearly distinguish the moderate and unimproved groups. With increasing treatment, however, the separation of classes becomes clearer.

Each index of delta activity, therefore, demonstrates a relation to the eventual short term clinical rating which is much like that demonstrated for the combined index of degree of delta activity.

The intercorrelations of each of these indices are shown in Table II. All correlations are significant at better than the 1% level of confidence, although the highest correlations with the degree of delta activity are noted for the frequency and amplitude measures. The lowest correlations are noted for the duration of burst activity. These observations indicate that in future studies or in clinical application frequency response and amplitude changes may serve as criteria for the degree of induced delta activity.

TABLE II

Intercorrelations of Individual Indices and Degree of Delta Activity

	Average Delta	Highest Delta in One Lead	Lowest Frequency	Highest Amplitude	Longest Duration Bursts	Degree of Delta Activity
Average Delta	---	+.98	-.79	+.72	+.67	+.80
Highest Delta in One Lead	+.98	---	-.67	+.72	+.68	+.84
Lowest Frequency	-.79	-.67	---	-.78	-.47	-.90
Highest Amplitude	+.72	+.72	-.78	---	+.57	+.88
Longest Duration Bursts	+.67	+.68	-.47	+.57	---	+.63
Degree of Delta Activity	+.80	+.84	-.90	+.88	+.63	---

3. EEG Delta Activity as Index of Clinical Outcome:

Following these observations, a study was undertaken to determine whether the degree of delta response was predictive of the short term therapeutic outcome. On the basis of the observation that the much improved patients had developed high degree delta activity early and had sustained such activity, electroencephalograms were obtained during the second and third weeks of treatment in 54 consecutive electroshock patients.

The records were scored as to whether high degree delta activity was achieved during both, one or neither of the 4-6 and 7-9 treatment periods, and the data was related to the clinical evaluations (Table III).

TABLE III

Patients with High Delta Activity during Second, Third weeks of Treatment *

		Clinical Rating		
EEG Delta		Much Improved	Moderately Improved	Unimproved
Both High	(18)	12 (67%)	4 (22%)	2 (11%)
One High	(16)	4 (25%)	8 (50%)	4 (25%)
None High	(20)	6 (30%)	7 (35%)	7 (35%)

Of the patients who manigest high degree delta activity during the second and third weeks of treatment, 67% were rated as much improved, while only 30% of patients without high degree delta activity were so rated. Thus, the early induction and persistence of high degree delta activity is seen to be related to the short term clinical evaluation.

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* Significant at the 2% level of confidence.

DISCUSSION:

The present study demonstrates a consistent relationship between the degree and duration of induced electroencephalographic delta activity and clinical evaluation of behavioral change. While it is conceivable that the difference between our results and previous reports may be due to a variation in population, it is more likely that methodological aspects are important factors. Serial records were obtained during the course of therapy, so that the sequence of electroencephalographic change was evident. The records were obtained at a constant time interval following a treatment. Finally, quantititative analyses of the records were made instead of relying on clinical impressions. Of other investigators of this problem, both Roth (2) and Hoagland et al (16), who carried out systematic EEG analyses, were also able to demonstrate a relationship between EEG variables and behavioral changes.

Two aspects of these observations warrant further elaboration: the relation and role of the induced neurophysiologic change to the behavioral response, and the significance of these observations for a theory of the mode of action of electroshock therapy.

(a) Relation of Neuro-Physiologic Change to Behavior:

Behavioral change is a consistent accompaniment of alteration in cerebral function. Changes in mood, language, attitude, judgment, thought process, perception, and insight attend changes in cerebral function, from whatever cause, and have been extensively documented in the neurologic literature.

In this study, electroshock has been shown to consistently alter the electroencephalogram in a fashion which we have come to associate with

states of altered cerebral function. The studies of Davis and Davis (18), Ostow and Strauss (19), Ostow and Ostow (20) and Jung (21) have affirmed the significance of diffuse delta activity as an index of altered brain function. Symmetric, dysrhythmic delta activity has been interpreted as evidence of dysfunction of midline hypothalamic centers - the centrencephalic system (19). Such activity is also indicative of an alteration in the state of consciousness, with more marked alteration being directly related to the duration, amplitude and frequency of the slow wave activity (18, 21, 22). The demonstrated relationship between induced delta activity and behavioral response after electroshock, therefore, permits the conclusion that changes in the centrencephalic system with attendant alteration in consciousness are the physiologic basis of the electroshock process.* A similar conclusion was presented by Roth (23) on the basis of his studies of the effect of thiopentone on electroencephalographic delta.

Another example of the relation of the electroencephalographic delta to behavior is seen in reports of epileptic patients. Landolt (28) (29) describes a young epileptic who was ordinarily pleasant, friendly and cooperative for his clinic visits. At these times, records were consistently dysrhythmic. On one occasion he was surly, irritable and withdrawn, and his EEG was without delta activity. On the subsequent visit, the EEG was again dysrhythmic and a behavioral "improvement" was noted. Similar observations have been reported by Brockman _et al_ (30) and Fabing (31).

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* The biochemical substrate of this process has received limited study. Emphasis has been placed on acetylcholine-cholinesterase change (24) (25), alteration in blood-brain barrier (3) and changes in ionic and protein equilibria (26) (27) by different investigators, without definitive conclusions.

In a previous study (4) we had applied the amobarbital test for brain disease (32) in a serial fashion to this group of patients, and reported a relationship between changes in this index of cerebral function and behavioral change. Were other tests of cerebral function to be applied in a similar serial fashion, it is anticipated that these, too, would demonstrate consistent changes during treatment and a relation to behavioral response, within the limits of the sensitivity of the test to reflect changes in cerebral function. In this context, electroshock may be said to be a method of inducing a state of altered brain function for extended periods, in order to achieve changes in behavior.

From this point of view, the development of a significant degree of electroencephalographic delta may be a readily determined guide in the rational management of electroshock therapy. In these studies we have examined various delta indices and/or the intercorrelations and have noted that the amplitude and the frequency of the induced slow waves are the best guide to the degree of delta activity. In patients in whom the behavioral response to electroshock is inconsistent with the therapeutic expectation, examination of the electroencephalogram may provide a criterion for clarification. If the induced slow wave activity is faster than 4 cps and lower than 100 microvolts in anterior temporal - ear lobe or anterior temporal - frontal lead combinations, then there is presumptive evidence of inadequate electroshock therapy. When frequencies less than 3½ cps and voltages higher than 100 microvolts are maintained for a number of weeks, the assumption may be made that an adequate degree of altered brain function had been induced, and that other factors, (environmental, personality, pathophysiologic) were operating to preclude a favorable behavioral response to electroshock. A similar application can be made for amobarbital tests (4)

or syntactic language after intravenous amobarbital (6).

(b) Theory of Electroshock Action:

These studies of the electroshock process have demonstrated that alteration in brain function is induced early and sustained in patients in whom the greatest degree of behavioral change is noted. We have emphasized high degree EEG delta activity and positive amobarbital tests as indices of altered cerebral function, with the knowledge that other indices of altered brain function, applied in the same serial fashion, may also show significant alterations and a relation to behavioral change.

We have been impressed that the ratings of improvement are value judgments of the behavioral response. All patients in whom cerebral changes are induced by electroshock manifest changes in behavior. The range of behavioral patterns induced under these conditions is wide. Only certain patterns are evaluated as improved, however, while others are regarded as "unimproved." "Improvement" is a special case of behavioral response, being a subjective evaluation on the part of the observer that the patient is "better." Electroshock does not induce "improvement;" it induces a milieu of cerebral activity in which behavior is different than before electroshock. To the extent that the induced behavior in depressed patients is perceived as less complaining, depressed, agitated or anxious, or in schizophrenic patients as less delusional, hallucinatory or excited, the patient is evaluated as "improved". When behavior, however, is perceived as anxious, agitated, paranoid, complaining, or withdrawn, it is evaluated as "unimproved." This particular type of behavioral pattern induced by electroshock, is dependent on a number of factors, such as personality (33).

Another aspect of the rating of improvement is the environmental response to the induced behavior. The modification of mutism, withdrawal and negativism to excitement, overactivity and irritability may be considered a positive movement by the therapist but a disorganization by the ward physician or family. The goals of the therapist and the family, and their expectations and tolerances, are significant factors in the behavioral response of the patient to therapy, and also, in the ratings of improvement.

These same factors are significant in the duration of the electroshock effect. The induced change in cerebral function persists for only 2-8 weeks following even intensive courses of therapy. In many cases, the behavioral response is limited to this period of altered brain physiology. When induced changes in behavior are not adaptive in the milieu of the patient, the behavior reverts to pre-treatment patterns. In other instances, the induced behavior is adaptive to the environment, and, we assume, sustained thereafter not by the initial change in brain function, but by the newly developed interaction of the subject with environment. That this is indeed true is seen by the frequent successful adaptation of the patient to the hospital milieu after electroshock, only to have a recurrence of symptoms when discharge planning is discussed or discharge is consummated. Altered brain function provides the physiologic milieu in which there is an altered interaction with the environment - the doctor, family or society.

These observations lead to the conclusion that electroshock therapy is a non-specific induction of persistent states of altered cerebral function. Such altered cerebral function provides the physiologic milieu for an alteration of the organism's adaptive interpersonal behavior. Changes are induced in perception, language, mood, recall, and judgment which constitute a

mode of interaction with the environment. The type of behavior induced under these conditions is dependent upon the personality of the subject, the environment in which the interaction occurs, and the duration of the state of altered cerebral function.

A similar view of the electroshock process was initially expressed by Weinstein, Linn and Kahn (1), who emphasized the interrelationship of neurophysiologic changes and behavioral response. This description of the electroshock process is also consistent with the observations of Ulett et al (34), Roth (2) and Aird et al (3).

The neurophysiologic-adaptive interpretation of electroshock provides an operational definition of the process which has promise of further elaboration and observation. Such a hypothesis also has application to an understanding of therapeutic process in insulin coma therapy, lobotomy and tranquillizing agents.

SUMMARY AND CONCLUSIONS:

1. Serial electroencephalograms obtained at weekly intervals in 24 consecutive patients referred for electroshock were quantitatively analysed for the degree of delta activity.

2. A significant relationship was found between the degree and duration of induced delta activity and clinical evaluation of behavioral change. The results were confirmed in a predictive study in an additional 54 patients.

3. Differences between these results and those obtained by others are explained in terms of differences in methodology.

4. A neurophysiologic-adaptive interpretation of the electroshock process is presented. It is concluded that electroshock is the non-specific induction of persistent states of altered cerebral function, providing the physiologic milieu in which changes in adaptive interpersonal behavior occur.

5. Improvement after electroshock is seen as a special case of behavioral response under these conditions. The rating is an evaluation by an observer depending on numerous factors, including the type of adaptation, the goal and expectation of the observer (therapist, family, or administrator), and the setting in which the behavior occurs.

Acknowledgement:

We wish to express our appreciation to Mrs. Helen Donovan, Miss Gayle Wankel and Mrs. Hannah Mosquera for their technical assistance in this study.

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LEGEND

Figure I.	Low Degree Delta Activity.
Figure II.	Moderate Degree Delta Activity.
Figure III.	High Degree Delta Activity.
Figure IV.	Relation of Clinical Ratings to Development of High Degree Delta Activity.
Figure V. (A - E)	Relation of Clinical Ratings to Each Index of Delta Activity.

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~~VII: 5/31/57~~

Relation of ~~Induced~~ EEG Delta Activity to Behavioral Response in Electroshock: Quantitative Serial Studies *

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VIII: 6-7-57.

Relation of ~~Induced~~ EEG/ Delta Activity to Behavioral Response in Electroshock: Quantitative Serial Studies.

Recent theories of electroshock therapy (1, 2, 3) have emphasized the role of neurophysiologic changes as the basis for the therapeutic action of electroshock. Consistent with these theories, we have observed a relation between changes in certain measures of brain function and behavioral response. We have noted ~~a relation between~~ that ~~ratings~~ Evaluations of clinical improvement following electroshock are related to ~~and~~ changes in orientation and confabulation after intravenous amobarbital (4), learning and recall (5), and syntactical aspects of language (6).

In view of these observations it could be expected that electroencephalographic studies would show a similar relationship. Numerous observers have reported consistent changes in the electroencephalogram after electrically induced convulsions. There is diffuse slowing with increased voltage and dysrhythmic activity (7 - 12). Fast activity decreases, both in voltage and in percent-time (13), and in patients who are intensively treated, there is a slowing of persistent alpha frequencies (14). The degree, duration and extent of delta activity is directly related to the frequency and number of grand mal convulsions (8 - 14). Such activity is usually symmetric, appears maximal in anterior leads, and the electroencephalographic effects usually disappear in 4-8 weeks following the last treatment (8, 9).

In contrast to the consistency of these observations, studies of the relationship between the electroencephalographic and the clinical changes show conflicting results. Chusid and Pacella (15), after an extensive review of the literature, concluded that the number of treatments rather than the degree of induced delta activity was the primary factor related to a favorable therapeutic response. On the other hand, Hoagland _et al_ (16) reported a relation between changes in the percent time fast activity (more than 13 cps) and independent clinical ratings of behavioral change. Roth (2) similarly reported a relationship between changes in the clinical condition and alterations in the delta response induced by intravenous thiopentone.

The divergent observations reflect variations in methodology. The present study is an attempt to apply quantitative methods of analysis of serial electroencephalographic records to this problem. The purpose of this study is to determine:

1) The relation of electroencephalographic delta changes to behavioral response in electroshock: and

2) if such a relationship exists, the significance it may have for an understanding of the electroshock process.

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SUBJECTS AND METHOD: a) In the initial series, twenty-four consecutive patients referred for electroshock were studied. Electroencephalograms were done prior to treatment, and at weekly intervals during and after treatment, using an 8 channel Medcraft electroencephalograph and needle electrodes. Recording was bipolar, and hyperventilation activation was utilized during each recording. During the treatment period, records were taken on the day following a treatment, generally 25 to 31 hours later.

Grand-mal electroshock therapy was administered by staff psychiatrists using a Reiter C-47 electrostimulator. Treatment schedules were three times a week, and the number of treatments varied from 9 to 33. As patients showed a clinical response, the psychiatrist tended to give fewer and more widely spaced treatments. There were 15 women and 9 men in the series, and the ages ranged from 24 to 68 with a median of 47.

Evaluation of EEG Records: A total of 160 records were obtained in these subjects. Following the suggestion of Strauss (17) the delta index was determined for three lead combinations (frontal-parietal, anterior temporal - vertex, and parietal-ear lobe) for 60 seconds of recording for each lead. The delta index is defined as the per-cent time occupied by waves of 7 cps or slower.

The run of each selected lead combination was scanned and 180 centimeters (60 seconds) of recording that was artifact free was noted. An additive map measure was run along the base of all waves of 7 cps or slower determining the number of centimeters occupied by such slow activity. The ratio of this figure to 180 was the delta index of that combination.

After these measurements were made, the record was scanned for the slowest frequency clearly identified at least twice in these selected lead combinations, and for the highest voltage of these slow waves. The total record was also scanned for burst activity. The duration of burst activity, the regularity (modulation) of the waves in the burst, and average voltage were noted.

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In the final estimates of degree of delta activity, the average delta index for the 3 lead combinations, the highest delta index in any one lead, the slowest frequency, highest delta voltage and duration of longest period of burst activity were listed for each record. The 160 records were arranged in sequence for each index and the percentile rank determined. The ranks were added and the records then arranged in rank order according to this score. On the basis that the higher score reflected a greater degree of delta activity, the upper third of the records were classified as "high degree delta", ~~record"~~, the middle third as "moderate degree delta" and the lowest third as "low degree delta".

High degree delta records were characterized by an average delta index of at least 18%; a ~~highest~~ delta index of 21% or more in one of the three measured leads; slowest frequency of less than 3 3/4 cps; highest delta voltage more than 100 microvolts; and a burst duration of at least 2 1/2 seconds.

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b) In a second series of fifty-four consecutive, unselected electroshock patients, electroencephalographic records were obtained prior to treatment, during the second and third weeks of treatment, and two weeks after treatment.

These records were analyzed using the identical measures as in the initial series. Using the original cut-off points, these records were classified into high, moderate and low degree delta records, and the initial observations were tested in a predictive study of therapeutic response.

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A. Much Improved: The 11 cases in this group were regarded as showing recovery or marked improvement. These patients no longer showed the symptoms which brought them into the hospital; their doctors felt they were better; and the nurses' notes confirmed such aspects as being able to sleep without medication, better appetite, and improved capacity to get along with others and participate in hospital activities.

B. Moderately Improved: The six patients in this group showed some improvement but continued to manifest symptoms of mental illness. These patients typically showed symptomatic relief, i.e., acute depressive features might be gone, but the dramatic change so evident in the first group was not apparent. Each patient continued to show some noticeable disturbance such as obsessional thinking, paranoid ideas, or somatic preoccupation.

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The initial analyses of the relation between the degree of induced delta activity and clinical ratings demonstrated a significant relationship between the early appearance of high degree delta activity and the "much improved" clinical ratings. Of the records in patients who were rated as much improved, 80% were classified as high degree delta in the second week; 91% in the third week and 88% in the fourth week of treatment. Of the records in patients who were rated as unimproved, none were high degree delta in the second or third weeks of treatment, and only 20% were high degree delta in the fourth week. The data is expressed in Table I, and graphically in Figure 4.

TABLE I

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An analysis of the relation between each of the five indices used in the final estimate of the degree of delta activity and the clinical ratings also shows significant correlations. In figures 5A to 5E ~~to 9~~, each index is related to the number of convulsive treatments and the eventual therapeutic evaluation. The curves for the highest amplitude delta (figure 5C ~~7~~) and the slowest frequency (figure 5D ~~6~~) are most similar to the curves for the degree of delta activity (figure 4).

The other three indices (figures 5a,b,e ~~5,6,9~~) clearly differentiate the much improved group from the patients in the other two ratings; but fail to clearly distinguish the moderate and unimproved groups. With increasing treatment, however, the separation of classes becomes clearer.

Each index of delta activity, therefore, demonstrates a relation to the eventual short term clinical rating which is much like that demonstrated for the combined index of degree of delta activity.

The intercorrelations of each of these indices are shown in Table II. All correlations are significant at better than the 1% level of confidence, although the highest correlations with the degree of delta activity are noted for the frequency and amplitude measures. The lowest intercorrelations are noted for the duration of burst activity. These observations indicate, that in future studies or in clinical application, frequency response and amplitude changes may serve as criteria for the degree of induced delta activity.

TABLE II

Intercorrelations of Individual Indices and Degree of Delta Activity*

	Average Delta	Highest delta in One Lead	Lowest Frequency	Highest Amplitude	Longest Duration Bursts	Degree of Delta Activity
Average Delta	---	+.98	-.79	+.72	+.67	+.80
Highest Delta in One Lead	+.98	---	-.67	+.72	+.68	+.84
Lowest Frequency	-.79	-.67	---	-.78	-.47	-.90
Highest Amplitude	+.72	+.72	-.78	---	+.57	+.88
Longest Duration Bursts	+.67	+.68	-.47	+.57	---	+.63
Degree of Delta Activity	+.80	+.84	-.90	+.88	+.63	---

* All correlations significant at better than 1% level of confidence.

3. EEG, Delta activity as Index of Clinical Outcome:

Following these ~~studies~~ observations, a study was undertaken to determine whether the degree of delta response was predictive of the short term therapeutic outcome. On the basis of the observation that the much improved patients had developed high degree delta activity early and had sustained such activity, electroencephalograms were obtained during the second and third weeks of treatment in 54 consecutive electroshock patients.

The records were scored as to whether high degree delta activity was achieved during both, one or neither of the 4-6 and 7-9 treatment periods, and the data was related to the clinical evaluations (Table III).

TABLE III

Patients with High Delta Activity during Second, Third weeks of Treatment *

		Clinical Rating	
EEG Delta	Much Improved	Moderately Improved	Unimproved
Both High (18)	12 (67%)	4 (22%)	2 (11%)
One High (16)	4 (25%)	8 (50%)	4 (25%)
None High (20)	6 (30%)	7 (35%)	7 (35%)

Of the patients who manifest high degree delta activity during the second and third weeks of treatment, 67% ~~are~~ were rated as much improved, while only 30% of patients without high degree delta activity ~~are~~ were so rated. Thus, the early induction and persistence of high degree delta activity is seen to be related to the short term clinical evaluation.

* Significant at the 2% level of confidence.

DISCUSSION:

The present study demonstrates a consistent relationship between the degree and duration of induced electroencephalographic delta activity and clinical evaluation of behavioral change. While it is conceivable that the difference between our results and previous reports may be due to a variation in population, it is more likely that methodological aspects are important factors. Serial records were obtained during the course of therapy, so that the sequence of electroencephalographic change was evident. The records were obtained at a constant time interval following a treatment. Finally, quantitative analyses of the records were made instead of Relying ~~reliance~~ on clinical impressions. Of other investigators of this problem, both Roth (2) and Hoagland et al (16), who ~~also~~ carried out systematic EEG analyses, were also able to demonstrate a relationship between EEG variables and behavioral changes.

Two aspects of these observations warrant further elaboration: the relation and role of the induced neurophysiologic change~~s~~ to the behavioral response, and the significance of these observations for a theory of the mode of action of electroshock therapy.

(a) Relation of Neuro-Physiologic Change to Behavior:

Behavioral change is a consistent accompaniment of alteration in cerebral function. Changes in mood, language, attitude, judgment, thought process, perception, and insight attend changes in cerebral function, from whatever cause, and have been extensively documented in the neurologic literature.

In this study, electroshock has been shown to consistently alter the electroencephalogram in a fashion which we have come to associate with states of altered cerebral function. The studies of Davis and Davis (18), Ostow and Strauss (19), ~~and~~ Ostow and Ostow (20) and Jung (21) have affirmed the significance of diffuse delta activity as an index of altered brain function. Symmetric,

~~dysrythmic~~ dysrhythmic delta activity has been interpreted as evidence of dysfunction of midline hypothalamic and thalamic centers — the centrencephalic system (19). Such activity is also indicative of an alteration in the state of consciousness, with more marked alteration being directly related to the duration, amplitude and frequency of the slow wave activity (18, 21, 22). The demonstrated relationship between induced delta activity and behavioral response after electroshock, therefore, permits the ~~further~~ conclusion that changes in the centrencephalic system with attendant alteration in consciousness ~~are~~ are the physiologic basis of the electroshock process. * A similar conclusion was ~~made~~ presented by Roth (23) on the basis of his studies of the effect of barbiturate on ~~EEG~~ electroencephalographic delta.

Another example of the relation of electroencephalographic delta to behavior is ~~to be~~ seen ~~on the occasional~~ in reports of epileptic patients. Landolt (28) (29) describes a young epileptic who was ordinarily pleasant, friendly and cooperative for his clinic visits. At these times, records were consistently dysrhythmic. On one occasion he was surly, irritable and withdrawn, and his EEG was without delta activity. On the subsequent visit, the EEG was again dysrhythmic and a behavioral "improvement" was noted. Similar observations ~~were~~ have been reported by Brockman <u>et al</u> (30) and Fabing (31).

In a previous study (4) we had applied the amobarbital test for brain disease (32) in a serial fashion to this group of patients, and ~~also~~ reported a relationship between changes in this index of ~~altered~~ cerebral function and behavioral changes. Were other tests of cerebral function to be applied in a similar serial fashion, it is anticipated that these, too, would demonstrate

* The biochemical substrate of this process has received limited study. Emphasis has been placed on acetylcholine-cholinesterase changes (24) (25), alteration in blood-brain barrier (3) and changes in ionic and protein equilibria (26) (27) by different investigators, without definitive conclusions.

consistent changes during treatment and a relation to behavioral response, within the limits of the sensitivity of the test to reflect changes in cerebral function. In this context, electroshock may be said to be a method of inducing a state of altered brain function for extended periods, in order to achieve changes in behavior.

From this point of view, the development of a significant degree of electroencephalographic delta may be a readily determined guide in the rational management of electroshock therapy. In these studies we have examined various delta indices and their intercorrelations and have noted that the amplitude and the frequency of the induced slow waves are the best guide to the degree of delta activity. In patients in whom the behavioral response to electroshock is inconsistent with the therapeutic expectation, examination of the electroencephalogram may provide a criterion for clarification. If the induced slow wave activity is faster than 4 cps and lower than 100 microvolts in anterior temporal - ear lobe or anterior temporal - frontal lead combinations, then there is presumptive evidence of inadequate electroshock therapy. When frequencies less than 3½ cps and voltages higher than 100 microvolts are maintained for a number of weeks, the assumption may be made that an adequate degree of altered brain function had been induced, and that other factors, (environmental, personality, pathophysiologic) were operating to preclude a favorable behavioral response to electroshock. A similar application can be made for amobarbital tests (4) or syntactic language changes after intravenous amobarbital (6).

(b) <u>Theory of Electroshock Action:</u>

These studies of the electroshock process have demonstrated that alteration in brain function is induced early and sustained in patients in whom the greatest degree of behavioral change is noted. We have emphasized high degree EEG delta activity ~~in the electroencephalogram~~ and positive amobarbital tests as indices of altered cerebral function, with the knowledge that other indices of altered brain function, applied in the same serial fashion, may also show significant alterations and a relation to behavioral change.

We have been impressed that the ratings of improvement are value judgments of the behavioral response. All patients in whom cerebral changes are induced by electroshock manifest changes in behavior. The range of behavioral patterns induced under these conditions is wide. Only certain patterns are evaluated as improved, however, while others are regarded as "unimproved". "Improvement" is a special case of behavioral response, being a subjective evaluation on the part of the observer that the patient is "better". Electroshock does not induce "improvement"; it induces a milieu of cerebral activity in which behavior is different than before electroshock. To the extent that the induced behavior in depressed patients is perceived as less complaining, depressed, agitated or anxious, or in schizophrenic patients as less delusional, hallucinatory or excited, the patient is evaluated as "improved". When behavior, however, is perceived as anxious, agitated, paranoid, complaining, or withdrawn, it is evaluated as "unimproved". This particular type of behavioral pattern induced by electroshock, is dependent on a number of factors, such as personality (33).

Another aspect of the rating of improvement is the environmental response to the induced behavior. The modification of mutism, withdrawal and negativism to excitement, overactivity and irritability may be considered a positive movement by the therapist but a disorganization by the ward physician or family. The goals of the therapist and the family, and their expectations and tolerances, are significant factors in the behavioral response of the patient to therapy, and also, in the ratings of improvement.

These same factors are significant in the duration of the electroshock effect. The induced change in cerebral function persists for only 2-8 weeks following even intensive courses of therapy. In many cases, the behavioral response is limited to this period of altered brain physiology. When induced changes in behavior are not adaptive in the milieu of the patient, the behavior reverts to pre-treatment patterns. In other instances, the induced behavior is adaptive to the environment, and, we assume, sustained thereafter not by the initial change in brain function, but by the newly developed interaction of the subject with environment. That this is indeed true is seen by the frequent successful adaptation of the patient to the hospital milieu after electroshock, only to have a recurrence of symptoms when discharge planning is discussed or discharge is consummated. Altered brain function provides the physiologic milieu in which there is an altered interaction with the environment - the doctor, family or society.

These observations lead to the conclusion that electroshock therapy is a non-specific induction of persistent states of altered cerebral ~~brain~~ function. Such altered cerebral ~~brain~~ function provides the physiologic milieu for an alteration of the organism's adaptive interpersonal behavior. Changes are induced in perception, language, mood, recall, and judgment which constitute ~~the~~ a new mode of ~~adaptive~~ interaction~~s~~ with the environment. The type of ~~adaptive~~ behavior induced under these conditions is dependent upon the personality of the subject, the environment in which the interaction occurs, and the duration of the state of altered cerebral function.

A similar view of the electroshock process was initially expressed by Weinstein, Linn and Kahn (1), who emphasized the interrelationship of neurophysiologic changes and behavioral response. This description of the electroshock process is also consistent with the observations of Ulett _et al_ (34), Roth (2) and Aird _et al_ (3).

The neurophysiologic-adaptive interpretation of electroshock provides an operational definition of the process which has promise of further elaboration and observation. Such a hypothesis also has application to an understanding of therapeutic process in insulin coma therapy, lobotomy and tranquillizing agents.

SUMMARY and CONCLUSIONS :

1. Serial electroencephalograms obtained at weekly intervals in 24 consecutive patients referred for electroshock were quantitatively analyzed for the degree of delta activity.

2. A significant relationship was found between the degree and duration of induced delta activity and clinical evaluation of behavioral change. The results were confirmed in a predictive study in an additional 54 patients.

3. Differences between these results and those obtained by others are explained in terms of differences in methodology.

4. A neurophysiologic - adaptive interpretation of the electroshock process is presented. It is concluded that electroshock is the non-specific induction of persistent states of altered cerebral function, providing the physiologic milieu in which changes in adaptive interpersonal behavior occur.

5. Improvement after electroshock is seen as a special case of behavioral response under these conditions. The rating is an evaluation by an observer depending on numerous factors, including the type of adaptation, the goal and expectation of the observer (therapist, family or administrator), and the setting in which the behavior occurs.

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LEGEND

Figure 1. Low Degree Delta Activity ~~Response~~

Figure 11. Moderate Degree Delta Activity ~~Response~~

Figure 111. High Degree Delta Activity ~~Response~~

Figure 1V. Relation of Clinical Ratings to Development of High Degree Delta Activity.

Figure V.(A-E) Relation of Clinical Ratings to ~~East~~ Each Index of Delta Activity.

Theory of ECT Actn: Roth.

Refers to his EEG report. "The Evocation of such latent EEG changes by thiopentone

(I) argues, in view of what is known of the site of action of barbiturate, in favor of a primary

(A) action by ECT on the diencephalon." p. 47

Second: change in sleep rhythm, appetite, wt, water metabolism and menstrual cycle are evidence of diencephalic involvement

Third: amnestic syndrome produced by ECT is reminiscent of concussion (cf Jefferson Brit Med J. 1943 I; 1 " Bull 1950, 6: 333) who argues that changes in consciousness due to diencephl. involve.)

IV: Korsakow may appear - this seen in corpora mamillary lesions.

V. Gellhorn's evidence.

(B) Nonspecific nature of ECT.

"It would seem more likely that ECT tends to eliminate qualitatively new behavior patterns that are recently acquired, and to facilitate restoration of the more firmly established framework of pre-psychotic personality." p. 53

Concludes therefore that the EEG + somatic changes have a "biologically purposeful character," for they appear as a concerted response by the homeostatic centers in the brain directed towards the restoration of the most stable and integrated organization of cerebral and metabolic activities hitherto attained."

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Beck : Effects ESt on Personality Arch NP 1943

Discussion of paper:

Joseph Rheingold:

"Dr. K. Eissler, in a psychoanalytic study of a group of shock-treated pts, found that the clinical changes were associated with greater docility, as a result of the blunting of the emotional and intellectual life. ....

" Dr. L. Bosher et al obtained EEG on pts before, during + after ECT "When there is no evidence of impaired mental function and no electroencephalographic alteration, clinical improvement does not occur."

EEG Effects of EST — Bosher, Darrow et al

Arch N P 1943

"the results suggest impairment of cerebral metabolism as a factor in the improvement following shock therapy" 108

~~109~~ Observed that EEG activity under shocking electrode showed "increase in potential, decreased frequency and decreased blocking of alpha". With continuation of treatment the EEG progressively acquired the characteristics of interseizure records."

Correlations of EEG during Brief Stim therapy. Liberson et al

Conf Neurol. ~~R~~ 16: 116.

Note: Using BST – Grand mal conv.

8/14 ~~#~~ subjects

(A) 2 wks – 5 Rx/wk
(B) 3 wks @ 4 Rx/wk.
(C) 4 wks @ 3 Rx/wk
(D) 4 wks @ 2 Rx/wk.
(E) the 3 wks. @ 5 Rx/wk
(F) " 3 wk @ 1 Rx/wk

	Δ	~~θ~~ + Δ
(A)	23%	55%
(B)	15%	47%
(C)	14	46
(D)	16	44
(E)	17	55
(F)	9.8	36.

Directly related to #Rx.

Maximum response initially.

EEG effect temporary.

Shows tendency for saturation.

"Psychol. deficit, on the other hand, is more definitely susceptible to the cumulative action of the increasing number of Rx"

Changes In Convulsive Threshold

Brodman, ... MLett —
Conf Neurol 1956

1) Convulsive threshold rises during treatments
2) " " is greater for photoshock than for Electroshock (measured by photo-pharm. thres) (may be a factor)

3) "Apparently it is the convulsion and not the convulsant drug that brings about the change in threshold since there was no change for the subconvulsive group"

4) "One can only speculate as to the role a change in threshold might play in effecting a change in mood. Certainly the convulsive seizure that occurs with ECT is widely accepted as having such action and among idiopathic epileptics it is not infrequently noted that a generalized seizure may clear up an incipient mood disturbance."

5) ".. in our studies both threshold change and clinical improvement were seen with convulsive - not with subconvulsive Rx, thus indicating that transient brain wave alteration and

myoclonic reactions are insufficient to produce either clinical improvement or to significantly alter the convulsive threshold." 103

Activated Electroencephalography

Kaufman, Marshall + Walker

Pts c Post-Traumatic Epi.

Arch NP - II 1947

1) HV - standard of 15 cpm difficult to achieve.

2) Hydration - a) 3000-6000 cc fluid/day b) Pitressin 0.5 cc q 2 h c) High CHO diet } but all pts → nausea vomiting had to be discontinued

3) Alcohol IV 40-150 cc 10% alc. - clinical evid of alc but 0 actual change in EEG

4) Trimethadione - IV 50-500 mg - no signif. effect.

5) ECT: { 200 mamp x 0.05 - 0.15 sec, 60 cycle. or 2-5 mamp x 2-3 sec } feeling of warmth -

no change in EEG.

6) Penicillin - 0

7) Sodium Cyanide - specific toxin for cytochrome oxidase system

2% NaCN IV 0.3 mg. - 0.4 mg/kg

→ Respiratory gasp in 8-20 secs followed by progressive slowing of EEG

(e.g. Inj $\xrightarrow{20 sec}$ gasp $\xrightarrow{+5 sec}$ 8 cps $\xrightarrow{+5 sec}$ 6 cps $\xrightarrow{+8 sec}$ 2 cps)

addition of inhaled amyl nitrite + 70 secs → normal recov

- nonspecific effect - epi + normal

8) ACH 100-300 mg ACH/aqueous IV rate 20-60 mg/min.

9) Metrazole 1 cc of 10% soln (100 mg) - no effect

2 cc - induced abn. in some subjects

Results: ① EEG: a) Localized changes in 60% of the 97 pts tests
b) in 10% generalized changes.
② clinical - 10 pts had focal conv.
14 " " generalyed "

Repeated activation elicited focus in 1/3 of pts.

In 39 pts surgery - in each instance focus demonstrated.

∴ Recommends - ı.v. Metrazole (100 mg) as activation

8/56

Martin: see ↓

Effect of HV on EEG of Schiz + Non Psychotic Subj.

Ruben: Arch NP - 1942

Subj: 35 ♂ Schiz 21-47 yrs. mean 32 ± 7 yrs.

35 control 17-51 26 ± 6. yrs.

30 breaths/min × 2 min. Repeated after 5-10 mins.

1) Alpha. no effect of HV

2) Delta appeared on HV in 55% of controls

+ 3% " schiz

i.e. Schiz unresponsive to HV.

which he correlates c̄ general unresponsiveness of Schiz

also: Angyal, Freeman + Hoskins. Physiologic Aspects of Schiz withdrawal

Arch NP 1940 44 = 621-626

Levy, Serota & Grinker - Arch NP 1942

1) 50% of pts showed EEG abn &
many showed OMS clinically.

2) Recovery in a few wks.

"Recovery or Improvement is apparently not dependent on the presence of such changes in cerebral function as are shown by our methods of EEG exam. and tests for mental status.

Pacella, Barrera & Kalinowsky

All pts show EEG abn - EEG changes reach max. in 6-8 R.

Max. EEG change does not mean max. clinical change

Note that schiz brains more resistant to EST & propose further studies.

9/27/55

1) Roth:

(a) Trans. improvement related to EEG changes

(b) EEG changes induced earlier by Phenobarbital

v Amytal test in bringing out changes.

(c) Concluded EST affects recently acquired behaviour.

2) Proctor & Gordon

(a) No fully recovered had ++ or +++ EEG change

(b) Conclude that appearance of widespread ~~EEG change~~ slow waves = little or no clin improvement

3) Kennard & Willner

(a) Emphasize change in fast activity c ECT (like Hoagland, et al)

(c) degree of EEG change related to type of pre-shock record

No Spec statement of EEG relation to improvement

GR 2-3896
Dr. Gibbons 6 Pm

Moriarty & Siemens Arch NP 1947

(a) Unilat. electrodes → bilat EEG changes of seizure result

(b) # Rx in Recov. & non-recov = (15 = 16)

(c) No signif trends of recov. & non-recovered EEG's.

(d) No relation of EEG disturb. & sensorial disturbances — not related.

(e) Preshock EEG = normal
(f) # + degree EEG change & # Rx
(g) Ret to normal in 2 wks.

(h) No diff EEG Recov. & non-recov

Weil & Brinegar Arch NP 57: 1947

1) Inc EEG abn c̄ Rx
2) Ret to normal in 2 wks.
3) Post EST records resemble EPI records.

Cf for refs

Hughes, Wrighton & Jordan

No relation between delta act &
disapp of symptoms
or the occurrence of memory loss or
confusion

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Psychosom Med 8 : 1946 246-251

13 women c̄ agit depr. - followed by ① Daily Malamud scale
② EEG
③ Ketosteroid Exc.

EEG analyzed by Brazier + Finesinger.

Obs: ① Correl. between Malamud scale + EEG
% time 13+/sec (fast freq).

i.e.: c̄ improvement, % time decreases
" relapse, " " increases.

[fast waves a reflection of tension?]

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re: Manuscript Number 286 "Relation of EEG Delta Activity ..." by Fink and Kahn

Dear Doctor Fink:

I am very pleased to inform you that your paper has been accepted by the Editorial Board for publication in the A.M.A. ARCHIVES OF NEUROLOGY AND PSYCHIATRY. It is planned to use your article in an early issue of the ARCHIVES.

Yours very truly,

ROY R. GRINKER, M.D.

Editor-in-Chief for Psychiatry

P.S. It is necessary for publication that you forward an additional copy of your paper directly to Mr. G.S.Cooper, Managing Editor, A.M.A. Specialty Journals, 535 North Dearborn St., Chicago 10, Illinois, as soon as possible. Thank you.

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C O P Y

Please return to MD Publications Inc., 30 East 60th St., New York, 22, by Jan. 2 1958.

Relation of Electroencephalographic Delta Activity to Behavioral Response in Electroshock, Quantitative Serial Studies. MAX FINK AND ROBERT L. KAHN. AMA-Archives of Neurology & Psychiatry 78: 516-525, November, 1957

In a study of the neurophysiologic correlates of convulsive therapy, serial electroencephalograms were obtained at weekly intervals in 24 consecutive patients referred for electroshock. The records were quantitatively analyzed for the degree of delta activity by measurements of the per cent time delta, lowest frequency and highest amplitude delta in the record, and duration of burst activity.

A significant relationship was found between the degree and duration of induced delta activity and clinical evaluation of behavioral change. The results were confirmed in a predictive study in an additional 54 patients.

Differences between these results and those obtained by others are explained in terms of differences in methodology.

A neurophysiologic - adaptive interpretation of convulsive therapy is presented. It is concluded that convulsive therapy is the nonspecific induction of persistent states of altered cerebral function, providing the physiologic milieu in which changes in adaptive interpersonal behavior occur.

Improvement after electroconvulsive therapy is seen as a special case of behavioral response under these conditions. The rating is an evaluation by an observer depending on numerous factors, including the type of adaptation, the goal and expectation of the observer (therapist, family or administrator), and the setting in which the behavior occurs.

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	1-3 Top 1/3	1-3 Middle 1/3	1-3 Bott 1/3	4-6 Top	4-6 Mid	4-6 Bot	7-9 Top	7-9 Mid	7-9 Bot	10-12 Top	10-12 M	10-12 Bot
Imp.	2 (25%)	1 (13%)	5 (63%)	8 (80%)	2 (20%)	0	10 (91%)	1 (9%)	0	7 (88%)	1 (13%)	
Mod. Sp.	0 (0%)	1 (20%)	4 (50%)	1 (16%)	2 (33%)	3 (50%)	3 (50%)	2 (33%)	1 (16%)	2 (40%)	3 (60%)	0
Unsp.	0 (0%)	2 (29%)	5 (71%)	0 (0)	3 (60%)	2 (40%)	0 (0%)	4 (57%)	3 (43%)	1 (20%)	2 (40%)	2 (40%)

Percentage High EEG Abnormality

	1-3 Top 1/3	1-3 Middle 1/3	1-3 Bott 1/3	4-6 Top	4-6 Mid	4-6 Bot	7-9 Top	7-9 Mid	7-9 Bot	10-12 Top	10-12 M	10-12 Bot
p.	2 (25%)	1 (13%)	5 (63%)	8 (80%)	2 (20%)	0	10 (91%)	1 (9%)	0	7 (88%)	1 (13%)	
d. Sp.	0 (0%)	1 (20%)	4 (80%)	1 (16%)	2 (33%)	3 (50%)	3 (50%)	2 (33%)	1 (16%)	2 (40%)	3 (60%)	0
[illegible]	0 (0%)	2 (29%)	5 (71%)	0	3 (60%)	2 (40%)	0	4 (57%)	3 (43%)	1 (20%)	2 (40%)	2 (40%)

Percentage High EEG Abnormality

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