RHYTHMIC SLOW DISCHARGES IN THE ELECTRO-ENCEPHALOGRAM

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"RHYTHMS" have been a part of the *lingua franca* of the electroencephalographer from the beginning, but in fact truly rhythmic disturbances are exceptional, more particularly among the slower discharges, where great irregularity is the rule. However, in connection with epilepsy it was noted at an early date that waves of a period of about one-third of a second did tend to occur in bursts of fair regularity, both of period and of form. Somewhat similar waves have been seen in association with brain tumours (Walter, 1936) and with trauma (Jasper, Kershman, and Elvidge, 1940) and have aroused speculation as to the possible association of such waves with epilepsy. The author's attention was drawn particularly to these "rhythmic delta" discharges by a number of cases of tumours which seemed to present a more or less specific appearance in the EEG, and accordingly it was decided to investigate their occurrence and possible significance.

In the epileptic the rhythmic slow discharge may consist of waves which approximate closely to the sinusoidal form or may present the more complex appearance of the "spike-and-wave". The latter is extremely variable in its manifestations and certainly no dividing line can be drawn between it and the simple sine wave, every degree of spike formation being seen from patient to patient and even, at times, in a single record. The spike-and-wave complex, therefore, cannot be excluded from this discussion, and indeed, because of its well established association, must occupy a high place, although the chief interest is centred on discharges of "organic" rather than epileptic origin. Many of the slow rhythms had been noted to be subject to change when the patients' eyes were opened or closed, and consequently the occurrence of a response to this type of stimulus has also been investigated; in order to obtain a more complete picture of this phenomenon the frequency range considered was up to 8/sec.

Many of the disturbances are so outstanding that no difficulty is experienced in placing them, but there is a borderline of ill-definition where it becomes difficult to decide, and objectivity is en-

dangered. Although the spike-and-wave complex is occasionally of this nature, it is chiefly in the assessment of rhythmicity and response to visual stimuli that trouble is encountered. These involve consideration of wave-form and the interplay of varying frequencies and amplitudes, a subject which has received surprisingly little attention from electroencephalographers, but has recently been discussed by Dawson and Walter (1944).

As is well known, any repetitive continuous vibration can be broken down, by Fourier analysis, into a fundamental and harmonics of various amplitudes, all of sine-wave form, the whole being the arithmetic sum of the components. The complex form of the EEG can be treated in this way, either mathematically or mechanically (Grass and Gibbs, 1938). As a rule the EEG is far from sinusoidal and seldom strictly rhythmic, and it is worth considering in what manner these irregularities may arise: first, the rhythms at their source may or may not be sinusoidal; secondly, distortion may be introduced in the overlying tissues, either cerebral, or skull and scalp, and also of course by the recording system; thirdly, more than one rhythm may be, and usually is, picked up by any pair of electrodes, the resulting record being the arithmetic sum of such rhythms. Of these alternatives it is most improbable that the second can be of real significance in producing gross irregularities, so the question becomes: is the EEG fundamentally sinusoidal, but rendered irregular by the summation of distinct rhythms in the recording system, or is it fundamentally irregular? In the former case the appearance of a "sinusoidal" rhythm in the record would be due to the relative disappearance of other rhythms; in the latter to an unusual mode of physiological activity. That some of the irregularity is due to the summation of distinct rhythms is sufficiently apparent, for example, when the alpha rhythm is blocked from a complex record by eye-opening; further simplification may be achieved by suitable electrode placement to discriminate in favour of one rhythm and against another—delta activity remains characteristically irregular, and regular activity is the exception. Dawson and

Walter have described the harmonic composition of the spike-and-wave and it is a matter of some surprise that such a complex wave-form can survive the effects of interference from other rhythms and appear in the record as an extremely regular formation. All the evidence of this type, and also the anatomical evidence to be produced in this paper, supports the view that the usual mode of slow oscillations in the EEG is irregular, and that regular slow oscillations are exceptional and significant. At the same time, for their recognition in the EEG a relatively large amplitude is essential. In Fig. 1 are shown the admixtures of sine-waves produced by a photo-mechanical oscillator: in (a) a 9/sec. "alpha" rhythm is mixed with a 7/sec. "theta" rhythm of half its amplitude; in (b) a $2\frac{1}{2}$ /sec. "delta" rhythm is added, and reaches twice the amplitude of the "alpha" rhythm in (c). It is apparent that the higher the amplitude of the delta rhythm relative to any other rhythms which may be present, the more certainly will it be recognized as rhythmic or arrhythmic; the matter is further complicated in the human EEG by fluctuation in amplitude of the components, a factor which is not present in the mechanical example. It is thus almost a prerequisite of recognition that the rhythmic delta activity should be of relatively large amplitude, but it is not suggested that this is one of its fundamental characteristics. For example, after a head injury, the decline in amplitude can be followed in serial records to a point at which the delta activity could not be recognized as rhythmic, were it not for the previous records. A further point which is brought out by Fig. 1 is the masking of rhythmicity even when the amplitude is relatively

FIG. 1.—Photo-mechanical Oscillograms. (a) 9/sec. rhythm mixed with 7/sec. at half its amplitude. (b) $2\frac{1}{2}$ /sec. rhythm added at half amplitude of 9/sec. (c) $2\frac{1}{2}$ /sec. rhythm increased to twice amplitude of 9/sec.

high. The faster components of the record have been chosen to have no simple harmonic relation to one another or to the "delta" rhythm, with the result that, in their sum, the periodicity, measured either between the peaks or on the base line, varies widely. Similarly there is quite considerable apparent variation in amplitude.

Some of the problems involved in the assessment of reaction to eye-opening and -closing are of the same type as those discussed above. One of a different order is the frequency of occurrence of the rhythms under consideration. When, for example, a spike-and-wave outburst occurs only once or twice during a long recording it is not possible to decide whether an apparent association with eye-closing is due to chance. When such an association has occurred it has not always been recognized at the time, and the opportunity for more careful testing has passed. The likelihood of the association being recognized is proportional to the percentage time of occurrence of the particular frequency.

The masking of one rhythm by another has been discussed by Dawson and Walter, particularly in relation to the masking of the 4–7/sec. theta rhythms by alpha rhythms. When a dominant alpha rhythm is blocked by eye-opening a completely unsuspected theta rhythm may be revealed, but if the theta rhythm also is blocked its existence remains hidden. In Fig. 2 (a) is shown a fairly

FIG. 2.—(a) Parietal recording showing 9/sec. alpha rhythm with superimposed 6–7/sec. rhythm. (b) Mechanical oscillogram showing interference between 9/sec. and $6\frac{1}{2}$ /sec. (4:3) rhythms of equal amplitude. (c) As in (b) but with the addition of an 11/sec. rhythm at half the amplitude of the other rhythms.

regular 9/sec. alpha rhythm, recorded in the parietal region; toward the right side of the record the regular rhythm breaks up to form the characteristic pattern due to the interference of two rhythms, of about equal amplitude, having the frequency ratio of 3:4 (cf. Fig. 2 (b)). By suitable electrode placement it was, in fact, possible to demonstrate the presence of a theta rhythm at $6\frac{1}{2}$ –7/sec.; had this not been so the existence of the theta rhythm could only have been inferred from the interference pattern. As Dawson and Walter illustrate, such

patterns are highly characteristic for ratios involving small whole numbers, and provided the two rhythms have approximately the same amplitude. When a third rhythm, even of smaller amplitude, is added the characteristic pattern is lost, particularly if the third rhythm does not bear a simple harmonic relation to either of the original components, as illustrated in Fig. 2 (c). Finally, it sometimes happens that in complex irregular slow activity, when the eyes are opened a change towards simplification takes place, of such a nature that one is quite unable to decide what it is, and is forced to ignore it.

From the above considerations it is clear that, in the selection of records showing response to visual stimuli, one is certain to be too conservative. There is, however, one pitfall for the unwary which leads in the opposite direction: that is the occurrence of slow beats or interference patterns, giving the appearance of a slower rhythm underlying the alpha rhythm, which of course disappears when the latter is blocked. Fig. 2 (a) shows a hint of such a spurious slow rhythm at 2/sec.

To sum up, it may be said that recognition of rhythmic slow activity is dependent upon its relatively large amplitude, and of reaction to visual stimuli of any rhythm upon its percentage time of occurrence, its relative amplitude and its frequency relationship to other rhythms present, usually the alpha rhythm. The response of rhythmic activity to visual stimuli is more easily recognized than that of arrhythmic activity.

Method

All the records were obtained with a two-channel Grass electroencephalograph, kindly lent to this hospital by Professor E. D. Adrian. Recording was bi-polar throughout, using silver—silver-chloride—saline-pad electrodes, held in place by a Butywave cap or modification of it. Many of the patients were examined twice and some more frequently.

An attempt has been made to discover the total occurrence of the following in a consecutive series of patients:—

(1) Spike-and-waves complexes, whether random or rhythmic.

(2) All other rhythmic slow discharges; the upper limit of "slow" has been arbitrarily set, by analogy with the "spike-and-wave" complex, at 4/sec.

(3) All waves, whether rhythmic or not, at less than 8/sec., and not being a slowed alpha rhythm, which exhibit a response to opening or closing of the eyes.

The reports on the records of these patients were reviewed and in all cases which might come under one of the above three categories (e.g. slow activity not specifically stated to be irregular) the original records were reconsidered. The reports are made on the cards of a punch-card index which means that they can be readily grouped according to age, pathology, etc. In order, so far as possible, to avoid sophistication the reports and records were considered in a random manner, and the above three groups defined, before any further

sorting was made. In selecting the more doubtful examples of rhythmic delta activity, consideration was given primarily to constancy of period, then to constancy of amplitude, and finally to constancy of wave-form, bearing in mind the effect of the other rhythms known to be present. In view of the well known phenomenon of the slowing which often occurs in bursts of spike-and-wave complexes, from perhaps 3/sec. at the outset to 2/sec. at the finish, the overall constancy of period does not seem as important as the periodicity of any given wave in relation to that of its immediate neighbours.

Results

The number of cases considered was 1,316, composed of:—

Epilepsy without discovered organic cause ..	245
Head injuries, recent and remote ..	532
Tumours ..	229
Abscesses ..	11
Others, not classifiable above ..	299

Only five cases were found presenting recognizable reaction to visual stimuli in the theta band (4–7/sec.); they showed no clear correlation with the other cases discussed and will not be considered further, except to point out that the figure would almost certainly be very much higher with methods of analysis other than visual, such as that of Walter (1943).

The frequency of the rhythmic slow waves* lay between 1½/sec. and 4/sec. and a response to visual stimuli was only found among rhythmic waves, so that all the waves responding to visual stimuli were also rhythmic, with the exception of those in one case of head injury, which were random in their occurrence. The total number of cases showing a delta rhythm was 70, and the number showing a response to visual stimuli was 24, with an additional four which were doubtful; it was only in the one case mentioned that the two phenomena were not associated; the correspondence is so close that the 71 cases will be regarded as a unified group. It is realized that, for reasons which have been discussed, the recognition of a change in the record in response to visual stimuli is most easy in rhythmic activity; however, it seems probable that other factors are involved, some of which are suggested below. The group of 71 cases comprises 26 epileptics, 20 tumours and one abscess, 17 head injuries, and 7 cases not classifiable in the foregoing. These groups will be described separately, but before doing so the age distribution of the cases will be discussed.

Of epileptic patients the average age was 19·3 years in the "rhythmic delta" group and 41·2 years in the remainder, of patients with tumours 28 years in the former group and 42 years in the latter, and of the patients with head injuries 18·8 years in the "rhythmic delta" group and 27 years in a control group, the composition of which will be described later. The average age in the "mixed" group was 14 years, for which it has not been possible to devise an adequate control. The correlations with age, or

* For the moment this term covers also all spike-and-wave complexes, though some were single and therefore could not be rhythmic.

FIG. 3.—Percentage of "rhythmic delta" cases in age groups, for epilepsy, tumours, and acute head injuries.

rather youth, are even more strikingly brought out by expressing the number of cases with delta rhythm as percentages of their respective age groups, which has been done for the three main categories in Fig. 3. The general outlines of the curves demonstrate the higher incidence of rhythmic activity in youth, although the figures are too small to give statistical significance to the individual percentages.

The age incidence of epilepsy, the association of "petit-mal" with youth, and the association of the spike-and-wave complex with "petit-mal" are so well established that a low average age was to be expected; that it was not lower is due to the weighting of the figures by large numbers of service personnel. No such age incidence was anticipated in the other groups, and there does not appear to be any ready explanation for it; it would seem that the synchronization of a large number of cells in a slow discharge is more readily achieved in youth, particularly about the second decade, than in later life.

Epileptic Group.—This paper is not primarily concerned with epilepsy, nor with the spike-and-wave complex. The latter is discussed here rather to give a background to the remaining rhythmic activity than for its own sake; these 26 cases, therefore, will not be described in detail, and only some particular points will be mentioned. The criterion

for inclusion in the group was the occurrence of "fits" for which no underlying pathology could be demonstrated; one or two patients had had a previous minor head injury, but without evident related sequelæ. The attacks complained of were mostly of the petit-mal type, but 11 of the patients had also had one or more major attacks, while eight had never been aware of minor attacks. In one of these latter a hesitation in speech, thought to be in the nature of a stutter, was demonstrated by the EEG to be in fact due to very large numbers of minor attacks, accompanied by single or double "spike-and-wave" complexes. One case not included in the above had been subject to episodes of violent rage for some years, which were considered epileptic by his doctor; the occurrence of outbursts of spike-and-wave in his EEG was thought adequate confirmation of this diagnosis.

The incidence of the disturbance in the EEG was bilateral and synchronous, or diffuse, in 23 cases, and unilateral and more or less focal in three. Localization of bilaterally synchronous rhythms may be difficult and in the earlier records was sometimes inadequate; subject to these limitations, their antero-posterior distribution was predominantly frontal with few exceptions.

Definite spike-and-wave complexes occurred in 19 of the cases, and were doubtful in two others.

As mentioned above, all spike-and-wave complexes were included for completeness, whether rhythmic or not. There was great variability in the number of complexes occurring in a burst; in one case the complex was always single, and in others occurred in pairs, while at the other extreme was a burst lasting 27 seconds; the form of the complex was equally variable. In any given case the bursts tended to be of fairly constant duration and form, except that bursts accompanied by clinical manifestations tended to be longer than those without, to be of greater amplitude, and to contain more clearly defined spikes. The point to be stressed here is the gradation which could be arranged: single spikes, single spike-and-wave, bursts of spike-and-wave, bursts in which the spikes are barely discernible, bursts of "sine" waves, and finally rhythmic waves which are continuous or change in amplitude only slowly; the gradation is perfect and smooth. With the exception perhaps of the first and last examples, all these may or may not be accompanied by manifest clinical changes; while there are no specific differences between the EEG outbursts in sub-clinical and clinical petit-mal there may be differences in the individual case, of which increase in duration of the burst is the simplest.

Of the five cases without spike-and-wave, in three the delta rhythm tended to be paroxysmal, the paroxysms being associated once in each case with a clinical petit-mal attack. In the remaining two the delta rhythm was more or less continuous but exhibited fluctuation in amplitude from maximal to zero in a manner similar to that of the normal alpha rhythm.

Two of the cases, one with spike-and-wave and the other with a continuous simple delta rhythm, showed definite reaction to visual stimuli; in contradistinction from the majority of the epileptics, the affected rhythms were occipital in distribution. There were four others in whom a response was probable, but not certain, all having spike-and-wave complexes.

Tumours.—This group contains 20 cases with delta rhythm out of a total of 229; 53 of these 229 were not fully confirmed as having tumours, though the evidence for a space-occupying lesion was considerable in all of them; in the remainder the tumour was actually seen at operation or post mortem, or demonstrated in an unequivocal manner by ventriculography or needling. All the lesions in the "rhythmic delta" group were similarly demonstrated, with one exception; although the site of each lesion was known, the extent of some was necessarily doubtful. At the time of investigation the length of history varied from 1 week to 5½ years, and averaged 14 months, so that the rate of onset does not appear to be significant.

The delta rhythm, from 1½–4/sec., was bilateral in 12 cases and unilateral in eight. Of the former, 10 corresponded with midline tumours (four in the posterior fossa) and the remaining two tumours, though arising in the left hemisphere, encroached on the midline. The distribution of the unilateral

rhythms corresponded fairly accurately with the tumour site.

The case which first drew attention to the bilateral delta rhythms has already been described and illustrated (Cobb, 1944), but to recapitulate briefly:—

Case 1.—D. S., a girl of 15, had an astrocytoma of the posterior commissure. Her EEG showed a bilaterally synchronous 2/sec. rhythm at up to 150 microvolts, blocked by eye-opening, and having a focus in each parieto-occipital region. This was associated with a 6/sec. rhythm at around 40 microvolts.

The significance of this was not fully appreciated at the time, but some months later a more sharply defined example of the same phenomenon was seen:—

Case 2.—B. M., a girl of 9½ years, had suffered for 3½ years from morning sickness. Every morning, shortly after rising, she was sick, and then felt quite well for the remainder of the day, though she never ate breakfast. For the last 3 months she had on waking, or soon after, a fairly severe occipital headache, which was relieved by the vomiting. There were no other complaints, and nothing of significance in her past or family histories. Examination (20.1.45) showed gross papilloedema, some hypotonia and inco-ordination of the left arm and leg, with a grossly ataxic gait. She did not swing the left arm and tended to fall to the left side.

The EEG report was as follows (Fig. 4a): "The alpha rhythm is doubtful—there is much 6–7/sec. rhythm at about 70 microvolts, which is probably theta rhythm, and also a small amount of 9/sec. rhythm, at 40 microvolts, which is probably the alpha rhythm. Long bursts of regular, almost sinusoidal 2/sec. waves occur at about 200 microvolts. They are bilateral and synchronous and show a focus in each occipito-temporal region, but the amplitude and persistence are greater on the left side. They are almost totally inhibited by eye-opening and initiated by eye-closing". In view of the previous case the report continued: "... suggests a tumour in the region of the posterior end of the 3rd ventricle, rather to the left of the midline. It is perhaps possible that a posterior fossa tumour could produce it as a secondary effect of dilatation of the 3rd ventricle".

This raised a doubt as to the correctness of the clinical diagnosis of left cerebellar tumour, so a preliminary ventriculography was performed; it showed symmetrical dilatation of the lateral ventricles and no filling defect of the 3rd ventricle or aqueduct.

At operation (23.1.45) the posterior fossa was explored and the left cerebellar hemisphere was found to be enlarged; an exploring cannula revealed a tumour mass, containing a cyst from which a few c.c. of clear, yellow fluid were withdrawn. The child's condition was too poor to admit of removal of the tumour and the wound was closed. After operation her condition improved steadily and she was discharged symptom-free on 14.3.45. During this post-operative period two further EEGs were performed: the first, eight days after operation, showed little change from the pre-operative record, except that the 2/sec. rhythm was no longer of greater amplitude on the left side (Fig. 4b). The second, 23 days after operation, showed great diminution of 2/sec. activity, particularly on the left side, where it could only be distinguished with difficulty; on the right side the amplitude was up to 100 microvolts, but the persistence after eye-closing was much less than before (Fig. 4c).

The remaining 10 cases include five tumours in the region of the posterior commissure, three cerebellar tumours, one left parietal tumour in which there was radiological demonstration of distortion of the Sylvian aqueduct, and one left frontal tumour

FIG. 4.—Case 2. B. M. (a) Pre-operative record showing blocking of delta rhythm and its preponderance on the left side. (b) Eight days after operation, showing the focus on the right side. (c) Twenty-three days after operation: delta rhythm only apparent on eye-closing; amplitude lower on the left side.

of enormous size. The cases will be very briefly reviewed:—

Case 3.—J. T., age 20, had only a week's history suggestive of rising intracranial pressure. A posterior fossa exploration was carried out but he died shortly afterwards, no tumour having been found. Post mortem revealed a fairly extensive astrocytoma of the upper part of the mid-brain, with a projection into the 3rd ventricle.

The resting EEG (30.10.42) of this patient showed a very confused mixture of waves from 2–7/sec. at up to 70 microvolts, but during hyperventilation a 2½–3/sec. rhythm was accentuated to over 250 microvolts and continued so for about 1½ minutes after H.V. had ceased.

This is open to the criticism that a hyperventilation response of this type is not uncommon in young subjects, but the 2½–3/sec. waves were certainly present in the resting record, though their rhythmicity was largely masked until their amplitude was increased by the over-breathing.

Case 4.—M. S., age 41, admitted (25.11.42) with a 6 weeks' history of rising intracranial pressure, had a posterior fossa exploration performed. This revealed no tumour, nor did it relieve her symptoms; 10 days later a right anterior 3rd ventriculostomy was performed, which also failed to bring relief, and she died 2½ months later. Post mortem showed a glioblastoma below the splenium, blocking the posterior end of the 3rd ventricle and extending to some extent into both hemispheres.

The EEG (30.11.42) showed a fair amount of 6/sec. rhythm at 50 microvolts, and, in the occipital regions, short bursts of 3/sec. waves at up to 90 microvolts. Localization was inadequate, but they were certainly bilateral and occipital.

Case 5. S. S., age 40, had suffered for a year from attacks of headache and diplopia, the latter becoming continuous. Following a ventriculogram (13.1.43) the posterior end of the corpus callosum was explored, and after dividing it a "reddish tumour was seen in the pineal region" which was evidently an infiltrating glioma. The patient did not long survive operation, and post mortem was refused.

EEG (8.1.43) showed bilateral rhythmic 4/sec. activity of moderate voltage, and some theta activity.

Case 6.—T. M., age 34, complained of headache of one month's duration (5.11.43). He had gross papilloedema, inequality of the pupils, Lt.>Rt., slight weakness of the left leg, and some sensory impairment in the left arm and leg. A ventriculogram suggested a corpus callosum tumour and this area was explored on 24.11.43. Haemorrhage was very troublesome, but a greyish tumour was exposed beneath the posterior end of the corpus callosum; further investigation, including biopsy, was not possible because of the difficulty in controlling the bleeding.

The EEG (10.11.43) contained two main frequencies, a 4–6/sec. rhythm, and a 2/sec. rhythm occurring in quite long, bilaterally synchronous bursts, at up to 180 microvolts, which could be blocked by eye-opening, though this was only momentarily.

Case 7.—A. A., age 17, had a history of 5 months' duration and complicated symptomatology, chiefly indicative of rising intracranial pressure. Ventriculography (4.7.44) showed a filling defect of the posterior third of the 3rd ventricle. The short history suggested a malignant tumour, so no attempt was made to remove it, a third ventriculostomy being performed with good relief of symptoms.

The EEG (3.7.44) showed a bilateral 6–7/sec. rhythm at about 60 microvolts, and a bilateral occipital 2–3/sec. rhythm at up to 100 microvolts. The regularity of this

was largely obscured by alpha and theta rhythms, but at times was quite apparent.

Case 8.—B. J., aged 14, had a 5 weeks' history of headache, vomiting, diplopia and dimness of vision, and clumsiness of the right hand for 2 weeks. She had intense papilloedema, bilateral 6th nerve palsies, and slight weakness and inco-ordination of the right arm and leg. Ventriculography on 26.1.45 showed a large cyst in the left occipito-temporal region, some internal hydrocephalus, and kinking of the Sylvian aqueduct. Subsequent 3rd ventriculostomy failed to benefit the patient and she died a month later. Post mortem disclosed an extensive glioblastoma in the left temporal and occipital lobes, passing across the midline to the right parietal lobe.

The EEG report on 24.1.45 was as follows: "The alpha rhythm cannot be distinguished with certainty, but is probably 9/sec. Anteriorly the record is relatively normal, though there is some 4/sec. activity. Toward the occiput there are two more or less regular rhythms: 6/sec. at up to 80 microvolts, and about 2½/sec. at up to 200 microvolts. The 4/sec. rhythm is also present but rather overshadowed. Phase reversal of the 2½/sec. rhythm occurs over a wide area of the occipital region".

Case 9.—J. W., age 14½. A case of cystic astrocytoma of the left cerebellar hemisphere, successfully removed on 9.5.42, about 4 months after the onset of symptoms.

Her EEG on 27.4.45 showed a wide variation of frequency and nothing of high amplitude, but a bilateral 2/sec. rhythm could be distinguished at about 50 microvolts.

Case 10.—N. L., age 26, was involved in a flying accident in February 1941, and was unconscious for 3 days. He was subsequently (August 1943) boarded out of the R.A.F. on psychological grounds, but by the following month there was clear evidence of an organic lesion. Following ventriculography, a posterior fossa exploration revealed a large, extremely thin-walled cyst, lying entirely superficial to the left cerebellar hemisphere and extending just across the midline. It was thought possible that this might have been of traumatic origin.

The EEG was a complicated mixture of rhythms, in which bilateral 3/sec. and 6/sec. occurred in bursts of high voltage.

Case 11.—J. J., age 29. A 7 months' history and clear physical signs led to exploration of the posterior fossa on 11.3.44; a soft, solid, infiltrating tumour was found in the left cerebellar hemisphere.

The EEG (9.3.44) showed frequent bursts of 3/sec. waves at up to 100 microvolts. They were bilateral but thought to be more frontal than occipital.

Case 12.—R. H., age 25. This woman had an enormous left frontal tumour, which was partly removed at operation, though its rearward limits were not defined.

The EEG contained three main slow components: 4–6/sec. at about 60 microvolts, rather more marked on the left side; rhythmic 3/sec. bursts at up to 150 microvolts, bilateral, frontal, but showing phase-reversal to the right of the midline; and random irregular 2/sec. waves, which were not localized.

This last case would appear to be of a rather different order from the others, and perhaps fits more aptly into the unilateral group which follows.

The cases with unilateral delta rhythms will not be described separately, but only some salient points outlined. There were four tumours on the right side: two frontal meningiomata, a meningioma which was primarily infratemporal, of such enormous size as to present in the mid-parietal region, and a glioma of unknown, and probably large,

extent in the hemisphere. The left-sided lesions were three gliomata in the temporal region and one case of secondary carcinoma of the frontal lobe, which was not directly confirmed. In all of these patients the EEG showed a disturbance which was maximal on the side of the lesion and closely related to it, though in one the focus was somewhat anterior to the tumour site. Most of the records were complex, but all showed a well-organized delta rhythm, and in the four left-sided lesions this was affected by visual stimuli, either diminished by eye-opening, or augmented by eye-closing, or both. This was not the case on the right side. It is suggestive that three of the left-sided tumours were associated with homonymous visual field defects, one rather doubtful, while three of those on the right were not; the remaining two patients were not sufficiently co-operative to be tested.

The single case of cerebral abscess can conveniently be considered here, being the only other space-occupying lesion associated with a delta rhythm.

Case 13.—N. C., a soldier age 20, was struck by a metallic F.B. on the right coronal suture 4 cm. from the midline. This metal passed backwards and medially, and came to rest at the midline; X-ray showed it in this position with a trail of bone fragments in its track. Twenty-four days after injury the wound was soundly healed without surgical intervention and the only abnormal signs were minimal weakness of the left face and arm.

EEG at this time (27.9.44) showed moderate voltage activity at 3–5/sec., generalized but with greater incidence on the right side (Fig. 5a).

He remained well for a month and was then discharged to a Convalescent Depot; the following day he had severe frontal headache with vomiting, and becoming progressively worse, was re-admitted 5 days after discharge. He now looked ill, and had early papilloedema; there was definite weakness of the left face and arm, and possibly also of the leg. On the following day he had two focal fits.

The EEG 3 days after re-admission had: "a continuous irregular background of slow waves, chiefly round 2/sec. and 4–6/sec., but at frequent intervals fairly regular bursts of 1½–2½/sec. waves occur, at over 200 microvolts". They were maximal in the right frontal area, though not well localized.

An abscess was found in the wound track and successfully dealt with in stages, the patient being finally discharged 5 months after his injury. A number of further focal fits occurred, but his abnormal signs had almost disappeared.

Thirteen days after removal of the encapsulated abscess (16.1.45) and 3 weeks before discharge, his EEG was similar to the last, but the delta rhythm at 2½/sec. was of higher voltage and showed a sharp right frontal focus (Fig. 5b).

Although this case is complicated by a penetrating head injury, it is evident that the rhythmic delta activity is related to the formation of the abscess. The persistence of the rhythm after the removal of its presumed cause is comparable with the findings in case 2, and possible with those following head injury.

Comment.—The 21 cases described above fall naturally into two groups, the unilateral lesions with corresponding unilateral delta rhythm, and the midline lesions with bilateral delta rhythms. The

latter group contains tumours in two distinct, though closely related sites, and it is necessary to consider whether the origin of the delta rhythm is the same in both. It is fully realized that no very precise anatomical localization is possible from this material, but seven of the tumours involved the structures at the posterior end of the 3rd ventricle, centred roughly on the posterior commissure, and it seems reasonable to suppose that the common factor in these cases is that involvement. In addition they comprise the majority of cases in which lesions of this area were confirmed. Tumours around the 3rd ventricle, not including the suprasellar region, which did not show rhythmic delta activity numbered five, of which three were colloid cysts lying more or less free in the ventricle, one was primarily in the right lateral ventricle and only had seedlings in the anterior part of the 3rd, and one was a left thalamic glioma. There were also four cases in which there was presumptive evidence of a tumour in this region, but both operative and post-mortem evidence were lacking. It is perhaps worth noting that the case of "akinetic mutism" described by Cairns *et al.* (1941) had a bilateral delta rhythm associated with a 3rd ventricle tumour.

It seems clear that the common factor in the production of bilateral rhythmic delta activity in cases 1, 3, 4, 5, 6, 7, and 8 is the involvement, directly or indirectly, of some part of the epithalamus, or a closely related structure. Is it possible to associate the delta rhythms found in the cases of cerebellar tumour, cases 2, 9, 10, and 11, with involvement of the same area?

In the first place, rhythmic slow activity is the exception with posterior fossa lesions, being shown by four out of a total of 38 such tumours. The 34 non-rhythmic cases included 16 tumours arising in or involving the cerebellum or lower brain-stem, 11 neurofibromata, and four cases not fully confirmed in site; finally there were three tumours confined to the 4th ventricle, two being small benign cysts, and the third an encapsulated solid tumour. These latter are of importance, as they presumably produced their neurological effects by a simple obstruction, uncomplicated by direct tumour involvement, and are therefore an argument against internal hydrocephalus as a cause of rhythmic delta activity.

In three of the cases, Nos. 2, 9, and 11, the extent of the tumours was not accurately determined at operation and extension upward into the mid-brain was possible, though not substantiated. It is assumed, therefore, that all four lesions were purely cerebellar in their direct effects, and confined to the left side; there does not appear to be any simple anatomical explanation for this left-sided preponderance, and the number of cases is too small to exclude the workings of chance.

There is fairly general agreement that infratentorial structures do not themselves produce recordable changes in the EEG, and any effect they may have upon it is exercised through supratentorial structures. It seems probable that these

FIG. 5.—Case 13. N. C. (a) First record before development of abscess. The slow sway was bilateral and probably artefact. (b) Third record, showing rhythmic delta focus.

FIG. 6.—R. E. Temporal injury with basal fracture. (a) Six days after injury. (b) Twenty-four days after injury: bilateral resting record. (c) Twenty-four days after injury: showing reappearance of delta rhythm after eye-closing, predominantly on the left side. (d) Twenty-four days after injury, after 3 minutes hyperventilation.

four cerebellar lesions produced their effect by some unusual distortion of the upper brain-stem, or interference with its blood supply. Colour is lent to this idea by the asymmetric diminution of rhythmic delta activity after operation in case 2, which also provides one further argument in the form of reaction to visual stimuli. It is difficult to believe that this could be imposed by infra-tentorial structures, and there is no reason to suppose a different mechanism from that of case 1, whatever that may be.

In the cases with unilateral delta rhythm it is more difficult to find any anatomical factor common to them all, and still less to the bilateral cases; their distribution extended throughout both hemispheres, some were expanding lesions, and some invading, though all were probably, or certainly, large. There is evidence of involvement of deep central structures in several, though not in, at least, the two right frontal meningiomas. This evidence consists of the known size and extent of the infra-temporal meningioma, the position of the metallic foreign body in the abscess, and the presence of a right homonymous visual field defect in two, and possibly three, of the left-sided cases. For the present it would seem that some of the unilateral rhythms may be of the same nature as the bilateral ones, while others are perhaps chance occurrences.

Reaction to eye-opening and -closing is not consistently seen, but occurs in all the left-sided cases, and three of the bilateral ones; in the former there is supporting evidence, in the form of field defects, for involvement of the visual pathway, though this, of course, is only the beginning of an explanation of the mechanism involved. In the bilateral cases no field defects were observed, though again an anatomical basis is suggested by the proximity of the lesions to the superior colliculi and the lateral geniculate bodies.

There were indications of raised intracranial pressure in all but one of the cases, in the form of papilloedema, high lumbar C.S.F. pressure, or internal hydrocephalus. Several authors (Walter, 1937; Williams, 1939) in writing of the effects of raised intracranial pressure, have described the generalized slow waves as characteristically rhythmic, but disagreement with this conception has been expressed in a recent paper (Cobb, 1944) and is maintained in this. The majority of the tumour cases in the total series had raised pressure, but all those showing rhythmic delta activity have been described above; in them rhythmicity was clearly associated with the tumour site, rather than with any effect of raised pressure.

Finally there is the subject of the relationship of delta rhythms to epilepsy, of importance because of the similarity of rhythms in this group to those associated particularly with petit-mal. Of the 209 patients with tumours whose records did not contain a delta rhythm, 88 had fits at some time before or during their stay in hospital—that is 42 per cent. The corresponding figures for the “rhythmic delta” cases were 2 out of 20, or 10 per cent. If

the abscess is included the figure becomes 14.3 per cent (Table I). Although the total number of cases (21) is too small to provide a reliable percentage it is quite clear that delta rhythms associated with

TABLE I.—SHOWING DISTRIBUTION OF FITS IN RELATION TO DELTA RHYTHM AMONG TUMOURS AND HEAD INJURIES

		Total	Fits	Per-centage
Tumours	“ Rhythmic delta ”	21	3	14.3
	Non-rhythmic ..	209	88	42.0
H.I. All	“ Rhythmic delta ”	17	3	17.6
	Non-rhythmic	515	105	20.4
Acute	“ Rhythmic delta ”	16	3	18.7
	Non-rhythmic ..	207	8	3.9
	Selected N-R ..	38	5	13.2

tumours are not an indication of a concomitant epileptic tendency. The fact that the percentage is considerably lower than that in the control group is probably explained by the weighting of the rhythmic group with a high proportion of non-cortical lesions.

Head Injuries.—This is a somewhat diverse group of 17 cases comprising both penetrating and non-penetrating injuries, with loss of consciousness in all but one. The plainest correlations within the group are with youth, as already mentioned (with two exceptions the patients were under 30), and with the lapse of time after head injury.

One patient was examined $3\frac{1}{2}$ months after injury, while all the rest were first seen within 16 days or less (average 9 days). In those patients who had serial records, rhythmic slow waves had disappeared in all but one by the end of 3 weeks. This is in agreement with the finding of Williams (1941) who, however, seems to have found rhythmic delta activity in a higher proportion of cases than occurs in this series, where it is something of a rarity—3.2 per cent. of all cases, or 7.2 per cent. of acute cases (up to 21 days post-traumatic).

Individual case histories will not be quoted but the main points will be summarized. Although the severity and site of injury varied widely, there was in the majority some evidence of basal injury, and this appears to be the only reasonably constant finding. This evidence varied from inequality of the pupils and oculomotor palsies, through basal fractures with bilateral C.S.F. otorrhœa, to definite signs of a severe lesion in the upper mid-brain. Seven of the cases were of this type and a further seven had more or less focal injuries with fractures in the petro-temporal region. The remaining three injuries consisted of a penetrating G.S.W. in the parietal region, a concussion with 10 minutes’ post-traumatic amnesia and no abnormal physical signs, and a frontal sinus injury. This last is of a rather different type from the rest, as it was the only case in which the slow waves were not rhythmic but

were blocked by eye-opening. This patient had an injury to his right orbit by a high-velocity missile, which destroyed the eye and frontal sinus and caused a small dural tear and cortical laceration. His record 12 days after injury contained random 3/sec. waves closely associated with the alpha rhythm, and no definite evidence of frontal injury. This case appears to resemble closely the series of scalp wounds due to high-velocity missiles described by Bickford (1944), though in these there was neither fracture nor dural penetration. In any case the relationship between his cases and those described in this paper would seem to be close, though the causative trauma (or neoplasm) was different.

The delta rhythm was bilateral and symmetrical in nine cases, bilateral but asymmetrical in four, and unilateral in four. There was good correlation between the presumed site of neurological damage and the distribution of the delta waves; all the seven cases with presumed basal injuries had bilateral rhythms which, when adequately localized, were occipital; two of the three penetrating injuries (the third is mentioned above) had corresponding unilateral delta foci; the remaining two unilateral rhythms were associated with temporal injuries.

The delta rhythm in nine of the cases showed a response to eye-opening or -closing, five of the rhythms being bilateral, one bilateral but predominantly left-sided, and three left-sided. None were on the right side, and there were, in fact, only two cases with predominantly right-sided rhythms. These observations are of the same order as those in the tumour group, but no coincident visual field defects were observed among the head injuries.

It is interesting to note that as recovery from the injury occurred, the delta rhythms tended to diminish in amplitude, but even more in amount, and in the later stages might only appear as a few waves, still of appreciable amplitude, after eye-closing. After complete disappearance from the resting record it was usually possible to reproduce them by over-breathing. That this was not the common response to hyperventilation in young people was demonstrated by the fact that the delta rhythm remained unilateral when it had previously been so in the resting record (Fig. 6).

In an early paper Williams (1941) concluded that these rhythmic slow discharges had no significant relationship to epilepsy (see also Williams, 1944). In seeking evidence on this point a considerable handicap is presented by the nature of the material at this hospital, which has consisted of Service personnel and civilians, the majority of the latter from London and its suburbs. In either case, on discharge from hospital, they have left the district and follow-up has been rendered difficult or impossible; when later sequelæ have developed some patients have been referred back, but more than presumptive evidence of the absence of sequelæ is lacking in the remainder.

None of the 17 patients had had fits prior to injury. After injury three had probable or certain fits:

- (1) The child, age 3, with mid-brain hæmorrhage, had repeated fits.
- (2) One man had a right focal fit shortly after injury.
- (3) A child of 4 years lapsed into unconsciousness shortly after injury; the unconsciousness lasted 20 minutes and was accompanied by restlessness and spasticity of the legs; it was thought by his doctor to be an epileptic attack.

In the "rhythmic delta" group the percentage of ascertained epileptics is thus 17.6 or, omitting the last case, 11.9 per cent. In the whole "non-rhythmic" group of 515 cases there were 105 epileptics, or 20.4 per cent.; however, a large number of these patients were referred to this hospital because of their epilepsy and the two groups are not therefore comparable. The acute head injuries are not subject to this objection, but numbers of them had normal or borderline records, and are not comparable with the "rhythmic" group which necessarily had very abnormal EEGs. An attempt has therefore been made to select a group of cases, from those with acute injuries, having records of comparable abnormality with those of the "rhythmic" group. Subject to the same difficulties of follow-up, five patients out of 38, or 13.2 per cent., had fits, compared with three out of 16 acute cases in the "rhythmic" group, or 18.7 per cent. (see Table I). These differences are not sufficiently striking to warrant the conclusion that rhythmic delta discharges are necessarily indicative of potential epilepsy, though the limitations of the investigation are fully realized, and time may prove the contrary.

The Mixed Group.—This consists of seven cases of various and sometimes dubious nature. They have youth in common, the eldest being 24 and the average age 14. The length of history varies from 1 week to 13 years.

Case 14.—E. E., age 21, admitted *in extremis* after 12 months' illness. She died 4 days later, and post mortem showed multiple small granulomata, possibly tuberculous, in the cerebellum and brain-stem.

EEG 3 days before death showed bilateral rhythmic 2/sec. waves of high voltage. The effects of eye-opening and eye-closing could not be tested, and the distribution was not adequately checked.

Although this record was rather inadequate it is fairly certain that the case is comparable with those with tumours of the upper mid-brain region, or possibly of the cerebellum.

Case 15.—J. R., a girl of 9, had an abrupt onset of left hemiparesis with loss of consciousness. Subsequently she showed steady improvement and it was supposed that she had had a cerebral hæmorrhage or thrombosis, possibly on the basis of a congenital vascular abnormality.

Four weeks after the commencement of her hemiplegia her EEG showed a sharp focus of rhythmic 2–3½/sec. waves at up to 150 microvolts, in the right parietal region. They occurred in well-defined bursts and were blocked by eye-opening.

This would seem to be comparable with similar

findings with unilateral tumours. It is the only example in the whole series of a strictly unilateral delta rhythm on the right side which was blocked by eye-opening; to confrontation there was no visual field defect.

Case 16.—J. H., a girl age 15, with a history of left-sided Jacksonian fits since the age of 2. A right frontal flap was turned on two occasions, at 8 and 14 years old, and revealed extensive cortical atrophy. EEGs on three occasions over a period of 7 months showed high-voltage rhythmic 3/sec. activity, some of it spike-and-wave, which was primarily right frontal, but in subsequent records became more widespread, and bilateral frontal.

This is the only example in 1,300 cases of spike-and-wave complexes associated with a verified organic lesion. Spike-and-wave complexes of a rather unusual type developed during the course of the illness of one further patient, following Cardiazol therapy. The nature of this illness was obscure and its manifestations protean, a tentative label of encephalitis being given to it. Four EEGs recorded during a period of 6 months, showed the development of a bilaterally synchronous occipital delta rhythm, responsive to visual stimuli; in the last record it occurred only after eye-closing as a burst of three or four waves, preceded by a single spike.

The fifth patient in this group probably also had an encephalitic lesion. The clinical signs were those of a cerebellar tumour, the presence of which, however, was not confirmed by ventriculography; following this investigation she made a rapid and almost complete recovery. Her EEGs were essentially similar to those of the patients with midline tumours. Records of the same type were seen in one of the remaining cases, that of a boy who complained of headache; there were no other complaints and no abnormal clinical findings, so that no definite diagnosis was made.

Case 17.—Three weeks' headache and one attack of giddiness in a woman of 24 (G. R.) were considered to be psycho-neurotic in origin. Her resting EEG contained a single one-second burst of 4/sec. waves. An exactly similar burst occurred during hyperventilation.

Although as a group these seven cases show little uniformity, individually several of them have points of resemblance to those in the more defined groups, and are not without value in demonstrating the variety of lesions which may give rise to delta rhythms.

Discussion

The three main points which derive from this review are: (1) the anatomical distribution of lesions producing rhythmic delta activity; (2) the relationship between rhythmic delta activity of "organic" origin and that of "epileptic" origin, particularly the spike-and-wave complex; and (3) the significance of "organic" rhythmic delta activity in its relationship to epilepsy.

(1) Though the distinction is not always perfect, rhythmic delta activity is usually either unilateral and focal or bilaterally synchronous, with or with-

out preponderance on one or other side. Although there are points in common between these two types it does not seem possible to postulate a single anatomical mechanism for all; when verifiable all the bilateral cases have shown a lesion in the region of the epithalamus, and a high degree of probability exists for a lesion in a similar position in most of the unverified cases. While some of the unilateral tumours and head injuries approach this region, others certainly do not, and the rhythmicity associated with these appears at present as a chance phenomenon. On the other hand it is noteworthy that a very high proportion of the cases, some of which have been described in detail, and including the idiopathic epileptic group, show 4-7/sec. rhythms, mostly about 6/sec. which in some cases form a dominant feature of the record. This "theta rhythm" has been ascribed by Walter and Dovey (1944) and Cobb (1944) to lesions in the region of the basal nuclei and thalamus.

On grounds of distribution and behaviour there is reason to believe that the alpha rhythm must have its origin in an area adjacent to that ascribed to the bilateral delta rhythm; rhythmicity, at least of bilateral rhythms, appears to be associated with an origin in basal structures, whether evinced as alpha, theta, or delta activity. Furthermore, the susceptibility of such rhythms to response to visual stimuli would seem to be not a function of their rhythmicity but of their anatomical origin. In passing, it must be said that it is not suggested that the recorded potentials are other than cortical, merely that the cortex can be driven by a sub-cortical pace-maker.

While the distribution of unilateral rhythms is about equal on the two sides, the preponderance of response to eye-opening or -closing is heavily on the left side (9 to 1, and one doubtful). No constant corresponding field defects were found, but from an electrical point of view the left hemisphere seems to be more susceptible to inhibiting stimuli than the right. In confirmation of this it has been noted that when there is an asymmetry of the alpha rhythm the lower voltage is more commonly on the left side.

(2) Considering more particularly the bilaterally synchronous epileptic discharge of the spike-and-wave type, two main mechanisms have been suggested to account for the synchrony: either that a focus in one hemisphere activates a similar focus in the other, with too short a time lag to be measurable in the EEG, or that a common sub-cortical focus triggers both hemispheres simultaneously. Evidence, of two different types, for the latter view has been provided by Jasper (1941), and recently by Hursh (1945). Further support is offered here, in the form of the similarity between the epileptic and non-epileptic types of rhythmic activity and the suggested site of origin of the latter. As a general rule bilateral spike-and-wave complexes are maximal anteriorly, while the converse is true of the "organic" rhythms considered here; it is noteworthy that in the two epileptics whose rhythms

were definitely blocked by eye-opening, their amplitude was maximal toward the occiput. It does not seem possible to postulate a single site of origin for both the spike-and-wave and simple "sine" wave forms of bilateral rhythmic delta activity, partly because of this variation in antero-posterior distribution and also because of the rarity of spike-and-wave forms with organic disease, though it does seem that the deep sub-cortical structures particularly favour the rhythmic mode.

On the other hand some cases of epilepsy are associated with activity which varies from a single spike or group of spikes, through a single spike-and-wave complex to short groups of complexes, all of these occurring apparently at random anywhere on the cortex. The complicated harmonic constitution of the spike-and-wave makes it difficult to believe that the components could be derived from different sources, though there is some evidence for this in the form of different electrical foci for the two components (Dawson and Walter, 1944). It is probable that the spike-and-wave is an essential expression of epilepsy but its distribution is subject to the same factors which govern the rhythms of "organic" origin, which may be related to sub-cortical lesions, or less commonly to cortical ones.

(3) In this series the association of symptomatic epilepsy with rhythmic delta activity is not confirmed and in fact the contrary is suggested by the tumour group, though the numbers involved are too small to provide a definite answer. However, there is no line which can be drawn between spike-and-wave outbursts having definite epileptic significance and delta rhythms apparently having none. A possible distinction is between paroxysmal bursts and those more or less continuous rhythms which rise and fall gently in amplitude; none of the "organic" rhythms were truly paroxysmal, with an abrupt beginning and end, but on the other hand, neither was all the epileptic activity, whether associated with clinical changes or not. Where the onset and ending are abrupt the probability of epilepsy is certainly high, and where they are not it remains in doubt.

General Hypothesis.—The state of affairs in a normal record with little or no alpha rhythm is exactly paralleled by that in a record, some weeks after head injury, which has shown a delta rhythm. In both the relevant rhythm may be absent until the eyes are closed, when a few rhythmic waves of moderate amplitude occur, dying rapidly away; in both the rhythm can be made apparent by hyperventilation.

Consideration of rhythmic delta activity from an anatomical aspect fails to demonstrate a common unifying factor in all cases, but analogy with the behaviour of the alpha rhythm suggests a tentative hypothesis of general application: the delta rhythm may be a rest rhythm, potentially present in all subjects, and possibly in all cortical areas, though normally held in abeyance by other cerebral activity. This preclusion is less perfect in youth, and in certain cerebral structures, such as those associated

with the epithalamus, and may be broken down completely by various factors, of which alkalosis (hyperventilation) and a low blood sugar, a "constitutional defect" (epilepsy), and destructive cerebral lesions (tumour, trauma, etc.), are the chief, but it may be reinforced by arousal stimuli such as opening the eyes.

Summary and Conclusions

1,316 cases have been scrutinized for:

- (1) Rhythmic slow activity (upper limit 4/sec.).
- (2) Spike-and-wave complexes of all kinds.
- (3) Blocking by eye-opening, or augmentation by eye-closing of all rhythms slower than 8/sec.

The factors involved in the segregation of these groups are discussed.

Apart from one case all reactions to visual stimuli (28) occurred in "rhythmic delta" cases, of which there were 71, composed of 26 idiopathic epileptics, 20 tumours and one abscess, 17 head injuries, and 7 unclassified.

In all groups there was clear correlation with youth.

Wide variation in spike-and-wave activity makes it impossible to draw any line between it and simple delta rhythms. Some "spike-and-wave" appears to be random and some more or less focal, but it is commonly bilaterally synchronous and usually frontal. In two epileptics a delta rhythm which responded to visual stimuli was definitely occipital.

In "organic" cases the delta rhythms are either unilateral and correspond with the site of the lesion, or bilaterally synchronous and occipital. Among the latter there is correlation, definite in tumours and probable in the remainder, with lesions of the epithalamic region. No correlation is found with raised intracranial pressure or internal hydrocephalus.

Response to visual stimuli may occur in unilateral or bilateral rhythms; in the former it is almost confined to the left side.

Despite the similarity of the "organic" delta rhythms to those occurring in epilepsy no correlation whatever is found in the tumour group between epilepsy and rhythmic delta activity; nor is this correlation apparent in the head injury group, but incomplete follow-up renders this less definite.

Correlation with a short interval between injury and recording is almost complete.

Distinction between "organic" and epileptic delta rhythms is not possible in borderline cases, but the epileptic outburst tends to be less continuous and more sharply paroxysmal, while the spike-and-wave complex is rarely associated with organic lesions.

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