ELECTRO-ENCEPHALOGRAPHY IN THE STUDY OF EPILEPSY.

Demonstration by Mr. W. GREY WALTER, M.A.
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(*Abstract.*)

THE electro-encephalogram (E.E.G.) is a record of the electrical potential changes of the brain as recorded by placing electrodes on the scalp without opening the skull. The technique is similar to that used in obtaining a electro-cardiogram, and in the apparatus shown three independent recorders are used, for reasons to be described later.

Since the potentials are very much smaller than those produced by the heart much greater amplification is necessary than in electro-cardiography. The amplifiers in this apparatus increase the size of the brain potentials some 10,000,000 times, and the form of the potential waves is made visible on the screen of a cathode-ray oscillograph similar to those now becoming familiar in television sets. Alternatively the waves can be photographed and made into a permanent record. For observation, the oscillograph spot (which is produced by the impact of an electron beam in a vacuum upon a fluorescent screen) is made to move regularly across the screen so that the potential changes from the brain are seen as wave-like oscillations. The frequency of the potential waves in the brain is extremely low, in normal people from 8 to 12 per second (alpha rhythm), in abnormal cases usually from 1 to 5 per second (delta rhythm). Other faster discharges have been described, but are not as yet of any great importance clinically. These low frequencies are below the audible range, and the brain discharges cannot therefore be turned into sound, but must be observed. The cathode-ray oscillographs for this demonstration are provided with " after-glow " screens, so that the persistence of vision is augmented and the slow waves are seen as such, and not merely as movements of a spot of light. Records may also be taken with ink-writing oscillographs, but this apparatus is not obtainable in this country as yet, though several ink-writing oscillographs are going to be imported from the United States.

In a normal person, the only prominent feature of the E.E.G. is the alpha rhythm, which comes from the parieto-occipital cortex and is seen usually only with the eyes shut and the mind at rest. The other parts of the brain do not normally produce any regular rhythms.

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It has been found that in certain neurological conditions, chiefly cerebral tumour and epilepsy, the affected part of the brain produces slow waves easily distinguished from the normal discharges, and these are called delta waves. In cases of cerebral tumour it may be shown that the tissue responsible for the slow discharge is not the tumour itself but the neighbouring cortex, which has been interfered with by the new growth, and there is some indication that the cortex produces delta waves in certain intermediate stages of dystrophy or degeneration, and these are often associated with œdema in the neighbourhood of the tumour.

In cases of epilepsy it has been found that in a population of "people complaining of fits", whatever the various causes may be, about 50% will show an abnormal E.E.G., and of those with abnormal records the great majority will be classified on clinical grounds as idiopathic epileptics, and of this number the great majority will be under 40 years of age.

Cases with a well-authenticated history of trauma do not usually show any abnormality; this is contrary to expectations, but nevertheless explicable, since it is probable that the slow delta discharge is an indication of fundamental cortical abnormalities which would not be expected in a patient whose condition was due to a splinter of bone or contracting scar causing mechanical cortical irritation.

In such cases of epilepsy as show an abnormal E.E.G. the abnormality consists of a continuous delta-discharge similar in many ways to that found in cases of cerebral tumour, but usually qualitatively different. This discharge goes on continuously and is not affected greatly by the administration or withholding of drugs, although it does show spontaneous fluctuations in size associated with fluctuations in the frequency of fits.

If the E.E.G. is taken during a fit very dramatic changes can be seen. Lennox and his collaborators in Boston distinguish three types of seizure discharge: a smooth slow rhythm of high potential associated with "psychomotor attacks", a slow rhythm with sharp spikes associated with "*petit mal* attacks", and a fast rhythm associated with "*grand mal* attacks". They have also found, and this has been confirmed by many workers, that in a number of cases, "sub-clinical" seizures can be detected by electro-encephalography even when the patient is unaware of the attack, which can be detected clinically only by careful and continuous observation of the patient's performance of some intricate task.

These findings, particularly the discovery that most young idiopathic epileptics show an abnormal resting E.E.G. can be of great assistance, not only in the diagnosis of epilepsy, but in its prognosis, and in following the course of treatment in certain cases.

It may be said without reservation that a delta discharge in the E.E.G. of a patient complaining of fits or showing a spasmodic behaviour disturbance is a certain indication that the patient is suffering from, or is likely to suffer

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from, what clinically can only be called idiopathic or essential epilepsy, and the prognosis in such cases is that associated with this condition.

Conversely a normal E.E.G., although not a certain sign of normality, is suggestive of the possibility of some element other than epilepsy, and the prognosis is correspondingly better than if the E.E.G. is abnormal. In a patient in whom hysteria is suspected the diagnosis can be clinched by inducing a fit. If the E.E.G. remains normal the fit is not a true epileptic one.

In the demonstration it is hoped to show both the normal alpha rhythm and an abnormal delta discharge from an epileptic patient.

Records and diagrams will also be on view.

Discussion.

Dr. PICKWORTH suggested a partial but incomplete explanation of the meaning of the delta waves as an attempt at readjustment of the psychic background to a more or less continuous disturbing effect, such as might occur from cerebral tumour, epilepsy or chronic nasal frontal sinusitis (which Mr. Grey Walter had found to show slow delta waves). This psychic background is analogous to that occurring physiologically as adaptation of the pupil with the intensity of light, the appearance of complimentary colours as a background to vivid-coloured objects, and the exclusion from consciousness of repetitive monotonous sounds, such as clock-tick. At higher levels similar mechanisms of adjustment of background no doubt existed, and a continuous disruption of such psychic background by the vascular irregularities produced by cerebral tumour, epilepsy or contiguous infective processes, might necessitate readjustments, the oscillation of which (analogous to hippus and past-pointing) became detectable as delta waves. The fact that such disappear with age would be due to improvements in the mechanism of readjustment.

Mr. GREY WALTER replied that he did not know very much about the psychic background of the patient because he had not had time to study it, but there must be some correlation. The fact that these two patients had enormous errors of cortex suggested to him that there must be some psychical upset and deprivation, but he would point out that the arrhythmicity of the waves would not involve some arrhythmicity of the cortical function. He had not been able to show any correlation with a similar arrhythmicity of function.

Dr. R. M. STEWART (Leavesden) said no one who had once seen a major epileptic fit could fail to be impressed by the sudden, dramatic and enormous distribution of motor energy which must carry in its wake a tremendous disturbance of body metabolism. It was no wonder that secondary changes should be found in the brain of the character described by Dr. Meyer, and it was to him a matter of surprise that these changes were not more widespread.

He had felt for a long time that a very profitable and alternative approach to the study of epilepsy would be to concentrate on minor epilepsy, *petit mal*, and he was interested to see from Mr. Grey Walter's records that this was being done. In the graphs Mr. Walter presented the speaker thought the patients had all suffered both from major and minor epilepsy, and he would like to ask whether any work was being done confined entirely to the subject of *petit mal*. The workers in his field were more likely to get valuable material than Dr. Meyer and his associates who were familiar with the reluctance of the *petit mal* patient to go to the post-mortem table.

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Mr. GREY WALTER said he felt very strongly that results would only be obtained by complete co-operation. The problem was very complex, and one could not have too much material of every conceivable sort, however negative it was. Even negative findings had been most interesting.

With regard to *petit mal* he did not mention the fits, but in the convulsions there was great electrical discharge. There was enough electrical energy, quite apart from muscular energy, to light a small lamp. This in itself was very interesting, and might account for some of the histological changes—the cells being literally electrified. The potentials produced in the brain were too large for any biometric cell membrane, therefore there must be several cell membranes in a series. It would be interesting to discover whether the discharge was post-central rather than precentral, and whether there were changes in other areas of the brain.

Dr. F. BACH (Sunderland) asked whether an aura had been detected on the apparatus preceding an epileptic fit.

Mr. GREY WALTER replied that in *grand mal* they found no good relation between the nature of the aura and the location of the discharge. At the beginning of the fit the electrical discharge appeared half a minute before the fit, so that in that sense an aura was detected. In *petit mal* the conditions were rather different. He had a number of cases of patients with hallucinations who tended to have foci in the temporal lobes. There was a different correlation. They did not know enough about the hemispheres to say whether they were true. There was an indication that an aura in *petit mal* was accompanied by a reasonably corresponding discharge.

Dr. W. D. WILKINS (Cheddleton) said Mr. Walter had told them that a fit was accompanied by a great electrical discharge, and he would like to ask whether they could assume that the discharge was due to every nerve cell being a minute electrical cell which, when the fit occurred, produced this very great increase in electricity. If so, that electricity must be produced by chemical change in the cell, just as it was in an electric cell, and they would get nearer to the mechanism of the fit.

Dr. L. C. COOK (Bexley) wondered if Mr. Grey Walter could give any information as to the time after the onset of epilepsy that the continuous delta wave rhythm occurred. He wondered if Mr. Walter had had a case where epilepsy had only recently started. Dr. Meyer had shown that after a few artificially induced fits there were histological changes in the brain, and Mr. Grey Walter, working on a case of cardiazol-induced convulsions which the speaker supplied, showed that actually between fits, or before a fit, the rhythm was normal. He took it that the delta rhythm was not actually due to the fits but to the whole diathesis.

Mr. GREY WALTER said with regard to the nature of the electrical discharges one had to assume that the cerebral neurone was like every other living cell in being essentially an electric battery. There was no single living tissue, cell or organ which did not produce electrical changes. If one assumed that the central nervous neurone possessed this property one could see that these electrical vessels were due to each individual neurone contributing electrical energy. It could be assumed that the terrific potentials produced by these cells would stimulate one another. In plants the touch which produced the sudden collapse of a branch acted by exactly the same mechanism as the discharge of the cerebral system.

With regard to the onset of the abnormal discharge, one of the records he had shown was of a patient who was examined before the first epileptic fit on account of behaviour disturbances. In that patient, and in a great many others, the discharge had been present and quite obvious some time before the first fit, and the patient had afterwards developed epilepsy of a classical type. That indicated that possibly the term " epilepsy " should be kept for the fit itself because they had those clinical states which might become fits. There was a condition underlying, as Prof. Golla said, an irritability of the nervous system, and it was quite probable that the word epilepsy was misused, although he could not think of a better word.

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With regard to the cardiazol case, he regretted he did not mention the observations made in collaboration with Dr. Cook on cardiazol, and Dr. Walk on triazol. They were that the cardiazol induced no abnormality before the fit, but during the fit an abnormal discharge, afterwards returning to normal. In the case of triazol there was a persistent abnormality, and of course with that particular drug there might be several fits. An injection of a drug which was eliminated quickly seemed to produce a single fit, whereas a drug which was eliminated slowly produced a persistent state and possibly several fits. From an electrical point of view an idiopathic state could be produced more easily.

Dr. PICKWORTH asked why, if a large scar was removed and a small one left behind, fits might still persist.

Mr. NORMAN DOTT replied that it depended on the personal susceptibility to epilepsy. If this was not very great the small scar was not sufficient to produce attacks and the patient was cured. If the susceptibility was great they would go on having fits even on the basis of a smaller scar. That was how he interpreted the results he had seen.

Dr. T. S. GOOD (Oxford) remembered being struck with the observation that often in the chronic epileptic the pulse tension varied to touch. A colleague and himself investigated a large number of epileptics during the fits and found there was always an uneven curve which did not seem to be affected during the fit, or in between. He mentioned this because of the vasomotor idea. He had been associated with a well-known electrotherapist, Dr. Towell, and some time ago he had a very low blood-pressure himself—he suffered from what was called sciatica—and Dr. Towell suggested the static chair. It might have improved the sciatica, but it certainly made a difference to his feelings. It was interesting that the static breathing improved a person with low blood-pressure, but did not relieve the person with a high pressure.

As a clinician he had noticed that during what was called thundery weather people who had dry skins reacted in a different way to the rather greasy-skinned person ; in the one case they were irritable and could not keep still, and in the other it was as though they were leaking electricity at such a rate that they had no energy. He would like to ask whether that was due to electrical tension or discharge.

Mr. GREY WALTER said that was one of the most interesting " hares " which had been started, but which they could not pursue very far, because it went back to problems which physicists were loath to tackle. It was a sound physical point that people were always in equilibrium with their surroundings regarding electrical charge, as with heat and cold. There was no doubt that there was a great deal to be learnt about the electrical exchanges in the body. Epileptic and other patients who showed this great discharge were getting their energy from somewhere, but were also losing energy. It was a fascinating subject ; they might or might not be making fools of themselves in including in their discussions some of the things which smattered of charlatanry, but were the forerunners of interesting discoveries.

Dr. V. FRIED (London) pointed out that recently on the Continent electrical shocks had been used to induce fits in place of cardiazol or triazol. He asked whether Mr. Grey Walter had had any experience of such electrical shock treatment.

Mr. GREY WALTER answered that he had not induced fits electrically in human beings. They had tried occasionally to stimulate the brain through the skull, but it was very painful for the patients, and they had not done anything with it. It was an interesting point and electrical shock might be better controlled than the pharmacologically-induced fit.

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General Review of the Papers.

Prof. F. L. Golla (Burden Neurological Institute, Bristol) said that the task assigned to him was to make a general abstract of the papers, but there were many reasons why, although he had undertaken the function, he did not intend to fulfil it in the traditional way, one being that time was limited, and the other that the papers had been so clear that it was not necessary to summarize them. He proposed to ask his audience to imagine how the varied pieces of information given during the last two days would strike a seeker for help in understanding and explaining epilepsy. There was one thing to bear in mind, namely, that everything that had been said pointed to the conclusion that when talking about epilepsy—that is to say, a cortical discharge occurring with a certain amount of spontaneity and conditioned very often by the environment—they were talking about a whole series of diseases, but for those who were interested in the function of the central nervous system, and particularly of the cerebrum, they were talking about conditions causing a rise of cerebral excitability.

Anyone who had acquantance with nervous physiology must believe that it was impossible to think of a splinter of bone or of any foreign body causing agitation and irritation continuously over a number of years. The thing was unthinkable experimentally. It was necessary in fact to assume that there was some condition fo cortical excitability which might vary from day to day and month to month, but which under certain circumstances—that is to say, the presence of some pathological condition or serious disturbance of function of the central nervous system—was operative when this primary excitability occurred. In other words, the people concerned were potential epileptics. A person might get up in a bad temper, grumble at his breakfast, and have a row with his gardener, but if the family took it in the right way it passed off, and next day he was himself again. Some suffered from these conditions more than others; those who were temperamental knew that they were suffering from a general increase of cerebral excitability. As psychiatrists, if the real significance of epilepsy were understood, some problems of the greatest importance to them would be on the way to solution.

Let it be supposed that in addition to this increased irritability which might occur in anyone at different times, there was a condition in which it found a focus where there was less resistance. Then, instead of a general irritative condition, there would be one spot which would " fire off " in a discharge. The actual physical energy generated in such a discharge was so enormous that it was a question how the rest of the brain supported it.

Such a rise of excitability might be considered as a chemical or biochemical phenomenon, something conditioned not by excitation or spread of stimulus from nerve cell to nerve cell, but by some change taking place in the body. One fact confirmed by all who had written about epilepsy was the excitability of the epileptic. The emotional system—that is to say, the vegetative system for expressing emotion—was known to be exceedingly unstable in such people.

In his able review Dr. Carmichael had rather tended to throw cold water on the possibility of some vasomotor explanation. It might be imagined that there was some disturbance of the circulation, just as a hot skin might be associated with a state of excitement, and, as a consequence, disturbance of the nutrition of the cortex. That would be the vasomotor instability to be looked for in the increased excitability of the central nervous system.

It had rightly been pointed out that the theories of the " vasomotor " school were not physiologically valid because there were other ways of interpreting them; but there was no time to go into details. On the other hand, such methods as those which they had been attempting to employ up to now, the estimation of the amount of blood going to and from the brain in the case of a fit, seemed to him a very poor way of determining whether such vasomotor disturbances took place at all. If there was a huge disturbance of that sort one would expect the patient to have very many more symptoms than he actually manifested.

The curious relationship between migraine and epilepsy was well known, and

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there was every reason to believe that migraine was a symptom of vasomotor disturbance. All that could be said was that there were certain conditions only to be associated with vascular disturbances which caused epileptic discharges in people whose nervous system so far as was known was otherwise normal—for example, the epilepsy in Stokes-Adams disease, the epileptiform discharges or epilepsy which accompanied the condition of failing heart when the patient was raised to a sitting position. Dr. Carmichael had given some reasons for thinking that all that could be done was to suspend judgment, but one or two forms of convulsive discharge might be referred to vascular disturbances and the vascular system generally appeared to be most easy to understand.

Dr. Tudor-Jones had given an interesting paper on water metabolism, but there again the same difficulty was perceived as in Dr. Carmichael's paper. He showed that there was no great disturbance of water metabolism with the amount of blood flowing to and from the brain, but a hopeful line of investigation was indicated if, instead of looking at the general metabolism, an attempt were made to determine the permeability of the cell membrane. One might imagine a condition occurring throughout the body manifesting itself by such increased permeability. They were in search of a general factor which could apply both to the normal and the pathological person, but in the latter found better circumstances within which to operate.

What were those better circumstances? He detested all sorts of pathological speculations. It was easy to imagine that in the vicinity of a cicatrized foreign body or with a mal-developed nutritional system there might be only just enough blood circulating, or just enough exchange to remove the irritative products and nourish the cells, and any change would affect that area in the pathological state, whereas in the normal person it would simply cause a condition of hyper-excitability.

He spoke with a certain amount of hesitation about the excellent work of Mr. Grey Walter, who was associated with him at Bristol. He had for the first time been able to show, what the American school had since confirmed, that in a large number of cases there were permanent areas of electrical disturbance bearing a striking resemblance to the areas found in the cortex when there was an underlying cerebral tumour causing pressure which impeded the freedom of circulation and the removal of waste products. He would not specify further than that, but it was exceedingly suggestive.

The work of Prof. Meyer indicated that the specific changes, on which they had relied for so many years, were only to a slight extent confirmed. The one point that he wanted to bring out was that the problem was not one for neurologists, or for those in charge of the insane, it was the wide problem of cortical excitability in general, and if it could be solved in epilepsy it could be solved in very many other directions.

As to the vasomotor system, where the intracranial pressure was increased there was brought about under certain conditions the disappearance of the normal electroencephalograph such as Mr. Grey Walter had demonstrated. It was also known that if a condition of alkalosis was produced, fits could be brought about and the condition was characterized by generalized vasoconstriction. In other words, there was a smaller supply and interchange of material in the cerebral cortex. At the present moment they had to " live dangerously " and be bold in their speculations because they had no definite pathology.

Dr. Watterson's paper was a scientifically-minded paper, to rejoice the heart of those who had to listen to so much inaccuracy on this subject. Dr. Watterson had reserved his opinion whether the vasodilator substance which prevented fits when given to animals and to human beings acted simply by relieving a condition of vasomotor spasm. To a great extent the answer had been provided by recent observations on the brain of animals, and where it was found that there was no vasomotor spasm to start with there was nothing to relieve. What had happened was that the brain had been supplied with additional blood and thus had overcome the disabiilty.

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Prof. Meyer had shown a normal cortex with dilatation of the vessels in the sub-cortical areas. If the physiological method had been employed and the skull had been opened and the cortex examined, it would have been found to be of normal colour, while all the time below it there was a disturbance of circulation. That should make one a little cautious when speaking of the vasomotor disturbance not being seen at the beginning of the fit at the time the epileptic cortex was exposed at operation. He had seen one with Horsley many years ago, when the patient had a fit on the operating table. Since then Penfold had made the observation that in cases of idiopathic epilepsy there was a continuous play of colours following the fits. Whatever the explanation, there was an abnormal vasomotor mechanism as well. It was quite thinkable that the vasoconstriction hypothesis was the right one, because one was looking at the surface and did not know what was happening down below.

His purpose had been only to give a resumé and to pay a tribute to the high degree of excellence which had characterized the papers. He preferred to take the subject on a broader basis and to suggest that all things pointed to a profound disturbance in those who suffered from epilepsy—a disturbance common to all persons, but which under certain conditions might be operative by so increasing the excitability of an ill-nourished portion of the central nervous system that it would " fire off " as an epileptic discharge.

Dr. PICKWORTH (Birmingham) said he was glad Mr. Norman Dott wanted them to return to the original meaning of the word epilepsy. Anything which was an expression of epilepsy, or one of the epilepsies, was rather confusing. They often spoke of *status epilepticus* without fits, which was misleading. He wished to ask Mr. Dott a question. Darling had operated many times on the brain and he had never on one occasion had an epilepsy result from an aseptic cut of the brain tissue; he had operated on cases that had had shrapnel wounds in the war and many years afterwards these little shrapnel fragments had been found encased in pus. In these cases he supposed there was very low-grade infection which had been continuing in the brain all these years, and the speaker wondered whether Mr. Dott had operated on a case which could be considered as suffering from, or having suffered from, low-grade infection and epilepsy had resulted.

Mr. NORMAN DOTT replied that he thought it had to do with the amount of scar-tissue produced. It was very rare for epilepsy to follow in these wounds. He was not sure that it was of great importance whether the scar-tissue was associated with infection or not. He thought it was just as much a precipitating cause of epilepsy as a chronic abscess or low-grade infection around a foreign body. As far as he could judge from a surgeon's point of view, as far as the local lesion was concerned, it was the extent of scar-tissue in the brain which really counted, whatever its origin.

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