THE RELATION BETWEEN THE EFFECTS OF THE BLOOD SUGAR LEVELS AND HYPERVENTILATION ON THE ELECTROENCEPHALOGRAM

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THE frequency and amplitude of the rhythms seen in the electroencephalogram (e.e.g.) are altered greatly in certain subjects when alkalosis is induced by over-breathing. The alteration may take two forms: first, an accentuation of abnormal rhythms present in the resting e.e.g., and secondly, a production of rhythms not previously apparent. These effects may occur alone, or together, and in each case the alteration is most marked in the slower frequencies, that is, those of less than 8 c./sec. Fast rhythms, that is, those of rate greater than 14 c./sec., are rarely accentuated or produced on over-breathing, except when they occur as a component of a specific complex, such as the wave and spike which is produced in some epileptics. The most common response on hyperventilation is the appearance of 2-3 c./sec. rhythms of high amplitude, often called delta rhythms, which are seen first in the frontal regions and later, though in less size, posteriorly. The occurrence of these slow rhythms at 2-3 c./sec. as a result of hyperventilation is generally referred to as "instability" of the e.e.g. on hyperventilation.

It has been thought that a delta rhythm easily elicited by, and persisting for more than 20 seconds after the cessation of, hyperventilation may be an epileptic phenomenon. Evidence has accumulated to show that this instability or easy elicitation of delta rhythms is not peculiar to epileptics, and is found in a variety of other conditions. Thus it is a normal response in children. Brill and Seideman (1941) found that 40 per cent. of normal children between the ages of 4 and 6 years produced delta waves on hyperventilation, 9 per cent. between 10 and 12, and slightly more than 9 per cent. in the 12 to 13-year period. Williams (1941), in a survey of 900 subjects including epileptics, psychoneurotics, those with post-concussive states and controls, found that 75 per cent. of those with an abnormal resting e.e.g. produced delta waves on hyperventilation. In a group of post-traumatic cases 45 per cent. of those with abnormal resting e.e.gs. were found to show instability on over-breathing (Heppenstall and Hill, 1943), and a correlation with the age at which the injury occurred was demonstrated; the younger

the person at the time of injury the more likely was the instability, or appearance of delta rhythms, to occur. Hill and Watterson (1942) in a study of a group of psychopathic persons found that of those with abnormal resting e.e.gs. about 70 per cent. showed instability on hyperventilation. Still further evidence that the production of delta waves on over-breathing is not specific to epilepsy is given by the work of Rubin and Turner (1942a) showing that such waves occurred in 55 per cent. of normal controls and 3 per cent. of a group of schizophrenics.

An abnormal resting e.e.g. is more frequently associated with the appearance of delta rhythms on over-breathing than is a normal resting e.e.g. At this unit, however, several controls who had no history of nervous and mental disease and who had normal resting e.e.gs. have been observed to produce delta rhythms on over-breathing. Osgood and Robinson (1940) found among a group of institutional epileptics, who had had no fits for 5-30 years, that 10 who had normal resting e.e.gs. produced delta waves on over-breathing.

It thus appears that the presence of delta waves on hyperventilation cannot be of value as a test for epilepsy unless specific complexes, such as wave and spike, are released. The production of 2-3 c./sec. rhythms seems to occur in varying degree in all groups studied, but no account has been taken of the physiological state of the subjects. By varying the level of sugar in the blood the response to over-breathing may be modified; even slight changes in blood sugar level may have a remarkable effect. Thus in a case reported by Hill, Sargent, and Heppenstall (1943) delta rhythms were elicited by hyperventilation at a blood sugar level of 97 mg. per cent., but not at 113 mg. per cent.; in the same case lowering the blood sugar level with intravenous insulin to 44 mg. per cent. caused the slow rhythms to appear one minute earlier during over-breathing than at a higher level of 88 mg. per cent. Studying cases of Addison's disease, Engel and Margolin (1942) found that in a fasting patient over-breathing easily elicited delta waves, but 30 minutes after the oral administration of glucose even 4 minutes of over-breathing did not alter the record from its

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resting state. Rubin and Turner (1942b), in a series of experiments on a schizophrenic patient, found that the delta activity produced on hyperventilation decreased as the blood sugar level increased and considered 120 mg. per cent. to be the critical level. Suppression or reduction of delta waves was noticed by Liberson and Strauss (1941) after intravenous glucose injection. This effect was greater in adults and adolescents than in children.

Davis and Wallace (1942) and Engel *et al.* (1944) stressed the need for knowing or controlling the blood sugar value when using over-breathing as a test of stability of the e.e.g. even though the blood sugar level was not thought to be the only factor determining the production of slow cortical rhythms. The latter authors made the interesting observation that the increased stability of the e.e.g. to hyperventilation at high compared with low blood sugar levels was not due to the raised blood sugar level preventing the same degree of alkalosis being attained. Brazier, Finesinger, and Schwab (1944) studied the relationship between hyperventilation and blood sugar levels in a group of 45 normal controls. Their results led them to suggest that the appearance of delta waves for 5 per cent. of the second minute of hyperventilation at a blood sugar level above 130 mg. per cent. be regarded as abnormal. Their subjects over-breathed at the rate of 30 respirations per minute with depth adjusted according to body weight. Only the potentials from the occipital cortex were examined.

Therefore, the facts already known are:

- (a) that there is a relationship between blood sugar level and the appearance of delta waves in the e.e.g. on over-breathing;
- (b) that delta waves have been observed to occur during alkalosis induced by over-breathing at fasting blood sugar levels in a wide variety of abnormal states and in normal people, that is, those with no history of nervous and mental disorder;
- (c) that raising the blood sugar above fasting levels has been shown to prevent the appearance on over-breathing of delta waves in a schizophrenic and in normal people.

The question that arises is whether raising the blood sugar level, in all subjects observed to show instability on over-breathing at fasting blood sugar levels, will prevent instability or appearance of delta rhythms on hyperventilation. If this is not the case there may be a particular clinical group in which, when the blood sugar level is raised, over-breathing may still produce delta waves. Under these circumstances it should be possible to indicate a simple test which could be used as a routine in electroencephalography to isolate certain clinical groups. The object of this work, therefore, has been first to find a suitable method for observing and assessing the effect of blood sugar level on the elicitation of delta rhythms on over-breathing and secondly, to study the e.e.g. during over-breathing at raised blood sugar levels in various clinical conditions.

Method

A three-channel Grass amplifying unit with ink-writing recorders was used. The e.e.g. was taken with the patient sitting erect and recorded simultaneously from four silver electrodes covered with saline pads and spaced 6 cm. apart in the frontal, precentral, postcentral, and occipital regions. The patient fasted for at least 4 hours before the test. After a short resting recording, a sample of blood was taken from the finger and the patient over-breathed at 20 respirations per minute for 3 minutes. A record was taken throughout hyperventilation and continued until the e.e.g. had returned to the resting state. The patient was given glucose, 50 gm. in water, by mouth, and the previous procedure carried out either once or twice at approximately 20-minute intervals depending on whether after the first interval the e.e.g. remained unaltered on hyperventilation. The blood sugar was estimated by the Hagedorn-Jensen method.

The ideal method for expressing the gradual change to predominantly slow rhythms during over-breathing is the use of an automatic frequency analyzer (Grey Walter, 1943). Unfortunately, when these experiments were carried out an analyzer was not available and a method of visual counting had to be used. The rhythms counted were divided into two groups, those of 2-3 c./sec. and those of 4-6 c./sec. Two periods were analyzed, 30 seconds before and 30 seconds after cessation of hyperventilation. As slow rhythms, particularly those in the 4-6 c./sec. band occurred in the resting record in most cases, it was necessary to eliminate these rhythms as far as possible when assessing the over-breathing response. The majority of slow rhythms in the resting e.e.g.s. occurred with amplitude less than 75 μ v., therefore this value was taken as the amplitude below which no slow frequency was counted. The slow rhythms elicited by hyperventilation usually appeared with amplitude greater than 75 μ v. and the use of this value as the lower limit did not exclude changes obviously due to hyperventilation. A count was made of the slow rhythms, in each of the three leads, during the 30-second periods, and the time during which these slow rhythms were present was expressed as a percentage of the 30 seconds. The figures given in Table 1 are an average of the values for the three leads. Table 1 shows the percentage time occurrence of the slow rhythms, 2-3 and 4-6 c./sec., having amplitude greater than 75 μ v. in period (b) 30 seconds before and period (a) 30 seconds after cessation of hyperventilation at fasting and raised blood sugar levels.

Results

The subjects examined (71) included epileptics (22), neurotics (17), psychopathic personalities (17), those with post-traumatic states (9), and 6 others who cannot be included in the above groups. All have been chosen because at fasting blood sugar levels the e.e.g. changes to predominantly slow rhythms during hyperventilation. In Table 1 the results are grouped according to the clinical classification.

Examination of the results as a whole shows that raising the blood sugar level markedly decreases the amount of slow rhythms present during over-breathing. In some cases countable slow potentials are still elicited at the raised blood sugar levels while in others the e.e.g. remains unchanged from the resting state. In the 71 subjects examined there appear to be two types, those in whom raising the blood sugar level prevents the appearance of slow rhythms, called for simplicity group 1, and those in whom slow rhythms still appear, called group 2.

TABLE I

			Percentage time occurrence					
Blood sugar, mg. per cent. . .			<110		110-130		>130	
Frequency, c./sec. . .			2-3	4-6	2-3	4-6	2-3	4-6
Period counted . . .			b a	b a	b a	b a	b a	b a
Case No.	Age	Resting, E.E.G.	Epilepsy					
5009	36	—	15 10	1 0	10 10	2 1	6 1	3 0
5006	23	+	23 22	9 3	.....	.....	6 0	11 5
5355	24	++	20 +	17 +	.....	.....	6 3	4 2
5568	26	+	.....	.....	8 1	6 3	6 0	8 1
645	20	++	36 21	15 7	5 8	4 3	4 1	6 3
3085	29	+++	40 24	7 9	11 3	11 5	8 2	8 0
4578	20	+	26 13	10 5	.....	.....	5 2	7 4
4449	18	++	+ +	+ +	.....	.....	3 2	0 0
5201	29	+	44 43	4 3	16 13	6 5	9 1	2 1
5760	29	+++	21 9	4 2	.....	.....	4 1	1 0
5287	19	+	21 21*	4 4*	12 2	2 1	4* 3	2* 2
5041	20	+	38 19	1 0	4 0	1 0	8 3	2 0
5239	24	+	17 9	1 1	5 3	0 0	3 1	0 0
4106	21	++	2* 3	6* 6	.....	.....	11 5	3 2
1459	35	++	19* 19*	1* 1*	.....	.....	4* 3*	1* 1*
5667	20	+	19 11	4 3	.....	.....	8 1	3 1
3516	20	++	+ +	+ +	.....	.....	12 9	1 0
5271	27	+	20 16	7 4	.....	.....	5 2	2 1
521	18	+++	.....	.....	spike and wave		spike and wave	
5191	17	++	spike and wave		.....	.....	spike and wave	
5767	18	+	spike and wave		.....	.....	spike and wave	
5172	38	++	spike and wave		.....	.....	spike and wave	
			Neurosis					
5351	19	+	9 3	1 0	.....	.....	0 0	0 0
4801	18	+	37 8	5 2	.....	.....	0 0	0 0
4800	18	+	+* +*	+* +*	.....	.....	0 0	0 0
4305	24	—	16 10	6 2	.....	.....	.....	.....
			0 0	0 0	.....	.....	.....	.....
5589	34	—	.....	.....	4 2	1 0	0 0	0 0
5195	21	—	72 21	0 0	12 3	0 0	0 0	0 0
4038	32	+	23 15	1 2	13 1	0 0	0 0	0 0
5306	21	+	13 2	3 2	0 0	0 0	.....	.....
4506	26	+	7 8	3 2	0 0	0 0	.....	.....
5694	29	++	27 9	0 0	.....	.....	0 0	0 0
5174	31	++	7 13	3 7	0 0	0 0	.....	.....
5117	20	+	7 11*	1 2*	.....	.....	0 0	0 0
4475	39	—	20* 11*	3* 0*	0 0	0 0	.....	.....
4767	25	+	9 6	7 3	0 0	0 0	.....	.....
4305	30	+	33 3	12 2	0 0	0 0	.....	.....
5595	32	—	9* 5	0* 0	0 0	0 0	.....	.....
4576	20	+	23 16	0 0	0 0	0 0	.....	.....
			Psychopathy					
5017	27	—	+* 0	+* 0	0 0	0 0	.....	.....
3628	22	+	19* 12	4* 3	.....	.....	0 0	0 0
5072	21	+	26 30	3 2	.....	.....	.....	.....
			0 0	0 0	.....	.....	.....	.....
3426	20	+	14 0	3 0	0 0	0 0	.....	.....
4387	26	+	21 19	6 7	0 0	0 0	.....	.....
4868	21	—	16 12	3 1	.....	.....	0 0	0 0
4329	20	+	45 31	6 5	0 0	0 0	.....	.....
3926	39	+	4* 7	1* 1	4 4	0 1	0 0	0 0
5166	30	—	.....	.....	12 5	2 0	0 0	0 0
3468	19	++	11 7	1 1	.....	.....	1 0	2 0
6007	20	+++	25* 15*	1* 0*	9 2*	4 1*	.....	.....
5656	20	++	+ +	+ +	.....	.....	8 4	3 0
5360	33	++	11 6	2 2	.....	.....	4 4	2 1
5137	37	+	20 44	2 2	25 10	1 1	8 4	1 0
5642	28	+	26 8	2 1	.....	.....	9 1	1 0
4147	21	++	12 4	4 0	.....	.....	13 3	0 0
5637	20	++	34 33	4 2	.....	.....	10 1	2 3

TABLE I—continued

Blood sugar, mg. per cent. ..			Percentage time occurrence					
			<110		110-130		>130	
			2-3 b a	4-6 b a	2-3 b a	4-6 b a	2-3 b a	4-6 b a
Case No.	Age	Resting, E.E.G.	Post-traumatic states					
4351	26	+	11 10	0 0	1 0	0 0		
5486	39	+	10 20	2 0	0 0	0 0		
5701	20	+	16 1	4 0	0 0	0 0		
5039	26	+	9 24	3 1	.....	.....	0 0	0 0
4429	29	-	10* 3	3* 2	0 0	0 0		
3585	40	+	21 15	5 2	7 5	3 2	0 0	1 0
5682	23	+	16 8	0 0	.....	.....	8 3	0 0
4213	22	-	30 21	9 5	9 5	2 1		
4230	25	+	27 12	1 0	4 3	1 0	7* 0	0* 0
			Miscellaneous					
3321	26	+	14 15	0 1	18 16	1 0	9 5	0 0
5135	20	+	31 9*	5 4*	.....	.....	5 1	5 2
4155	31	-	5 1*	0 1*				
			0 0	0 0				
5290	20	++	12 3	1 1	.....	.....	0 0	0 0
4791	21	+	18 25	4 3	0 0	0 0		
1219	26	+	35 30	8 7	.....	.....	8 7	4 2

Classification of resting E.E.G.: -, normal. +, mildly abnormal. ++, moderately abnormal. ++++, severely abnormal.

* Value low due to masking by movement and muscle artefacts. Where a + sign is given instead of an actual amount for the percentage time occurrence the recording was not taken with the electrodes in the specified positions.

In the first group both the 2-3 and the 4-6 c./sec. rhythms elicited at fasting blood sugar levels on over-breathing may be prevented from appearing both during and immediately after hyperventilation if the blood sugar level is raised. Since sufficient time for the system to recover from over-breathing must be allowed between tests and since, in most cases, the blood sugar level rises rapidly after the ingestion of glucose the actual value of the blood sugar at which the response to over-breathing becomes stable cannot be determined. In this first group 20 subjects have been found in whom instability on hyperventilation has been abolished by raising the blood sugar level to less than 130 mg. per cent. In the other 15 subjects the blood sugar level rose to above 130 mg. per cent. before the second hyperventilation was done; opportunity to repeat the test to determine whether the response would have been stable at a much lower level did not occur. However, the available results suggest that if raising the blood sugar above fasting levels will stabilize the response to hyperventilation, it will do so at a relatively low value. Other workers (Davis and Wallace, 1942; Rubin and Turner, 1942b; and Brazier, Finesinger, and Schwab, 1944) have suggested that 120-130 mg. per cent. is the critical blood sugar level.

In the second group the final hyperventilation test has been made in 9 subjects with blood sugar values between 130 and 150 mg. per cent., and in

25 subjects with values between 150 and 210 mg. per cent. Although they may belong to this group, 2 subjects (4213 and 6007) have not been included, as the final blood sugar level has not been sufficiently high to give a conclusive result. In 4 subjects over-breathing produced spike and wave complexes. These complexes are composed of numerous frequencies including those slow rhythms counted and presented in Table I. Therefore, since raising the blood sugar level even as high as 200 mg. per cent. does not prevent the spike and wave complexes being released, these 4 subjects have been included in the second group. It would be interesting to study more cases in which spike and wave complexes are released by hyperventilation since the findings in the above-mentioned 4 subjects are not in agreement with those of Williams (1941), who states that the wave and spike pattern released on over-breathing may be inhibited by raising the blood sugar level.

Modification of all the slow rhythms elicited on hyperventilation does not apparently take place to the same extent when the blood sugar level is raised since whereas the 2-3 c./sec. rhythms are invariably decreased in amount, the 4-6 c./sec. rhythms may remain in similar quantity or even be increased. This effect may be actual or may be due to the inability of the eye to see the 4-6 c./sec. potentials in the presence of high amplitude slower rhythms. The latter view is more probable, and it seems unjustifiable to discuss the 4-6 c./sec. rhythms until an

improved analysis of the e.e.g. records is available. In group 2, 2-3 c./sec. rhythms of more than the critical size of 75 μ v. occur at blood sugar levels above 130 mg. per cent. in every case in period (b), and in the majority of cases in period (a); the lower times of occurrence in period (a) compared with those in period (b) are due to the fact that the e.e.g. has usually returned to the resting state before the thirty seconds have past.

Having divided the cases into 2 groups the possibility of a correlation between the groups and other factors arises. The three factors that have been investigated are age, degree of abnormality of the resting e.e.g., and the clinical diagnosis. The results are given in Tables II and III.

TABLE II

Group	Age		Resting E.E.G.	
	<20	>20	-, +	++, +++
1	9	26	33	2
2	14	20	18	16

TABLE III

Clinical diagnosis	Group 1	Group 2	Doubtful
A. Epilepsy	0	22	—
B. Neurosis	17	0	—
C. Psychopathy:—			
Aggression	2	3	1
Others	7	4	—
D. Post-traumatic states ..	6	2	1
E. Miscellaneous ..	3	3	—

It is known that there is a relation between age and instability of the e.e.g. to hyperventilation in children and adolescents. The e.e.g. becomes more stable as the age increases. If this change continues in adults the difference between groups 1 and 2 might therefore be due to age. In order to test this possibility the subjects in groups 1 and 2 have been divided into those less than 20 years old and those more than 20 years old. No correlation between age and the group into which a subject falls can be shown, see Table II [$\chi^2=0.76$, P lies between 0.5 and 0.3].

In order to see whether a relation exists between the group into which a subject falls and the nature of that subject's resting e.e.g., four classifications of the resting e.e.g. have been used, normal and mildly, moderately and severely abnormal. The cases have been divided between the normal and mildly abnormal on the one hand and the moderately and severely abnormal e.e.g.s. on the other. The results of this division, given in Table 2, show that the degree of abnormality of the resting e.e.g. is a significant factor in determining into which group a subject may be expected to fall. Thus, where a

resting e.e.g. is more than mildly abnormal, and the response on hyperventilation is unstable at fasting blood sugar levels, there is a great probability that the response at raised blood sugar levels will also be unstable. The probability is less that a normal or mildly abnormal resting e.e.g. will be associated with stability on over-breathing at raised blood sugar levels. A degree of cortical instability may therefore be revealed which is unexpected from the nature of the resting e.e.g.

Before considering groups 1 and 2 in relation to the clinical diagnosis a description of the case material, summarized in Table III, is given. Group A consists of 22 epileptics including service patients, civilian out-patients of this department, and a few patients from an epileptic colony. The ages vary from 17-38 years, giving a mean of 24.2. The majority have had more than one type of fit and have an associated personality disorder. In 12 subjects fits have developed within the last year, and in the remainder have been present for several years or since birth. One subject suffered a minor head injury since the onset of fits and another (3085) is considered to be suffering from traumatic epilepsy. Group B consists of 17 neurotics with ages varying from 18-39 years, mean 25.8, and includes patients showing anxiety or hysterical reactions. Slight cerebral trauma has occurred in 4 subjects (5517, 5351, 5595, and 4035) and moderate trauma in one (4801), whose clinical condition is not attributed to the injury. A history of epilepsy in a brother is alleged in 2 subjects (4801 and 5589). Group C consists of 17 patients with psychopathic personalities and ages varying from 19-39 years, mean 24.9. These 17 patients form a rather mixed group and are not clearly divisible into those who are predominantly aggressive and those who are predominantly inadequate, although 6 belong clearly to the former class (4171, 5360, 5017, 6007, 5642, and 4329). There are 3 cases of perverse sexuality (4171, 5166, and 3926), one of which (4171) is predominantly aggressive and therefore has been classified as such in Table III. One subject (3426) has been convicted for murder and another (5656) is a malingering psychopathic young woman charged with robbery. In 8 subjects there is a history of alleged concussion, and in one other, with a life-long personality disorder (6007), a head injury of moderate severity. There is a suggestion of epilepsy in the history of 3 of the subjects. One of these (4868) has had "sun-stroke" in England and at the time had "mainly fits." He has had no other epileptiform activity at any time. Another (4329) has had attacks of dizziness since aged 17, when he started boxing, and has fallen, hurting himself. The third (3468) fainted with incontinence as a child. In none of the 17 psychopathic patients has a family history of epilepsy been reported. Group D consists of 9 patients who have been examined because of symptoms following head injury, and all but one received the injury more than a year previously. The ages vary from 20 to 40, mean 27.8. There is a definite history of fracture in 3 cases (5683, 4213, and

4230). In 7 subjects the duration of post-traumatic amnesia was an hour or less, in one (5701) it was 15 hours and in another (5682) four days. No family history of epilepsy has been given in any of the 9 cases. A miscellaneous group, E, of 6 patients includes a patient with personality disorder following cerebrospinal meningitis (4155), a schizophrenic who has had fits on insulin treatment (1291), a life-long enuretic without spina bifida (3321), a patient with congenital alexia (4741), a service patient who has had a period of amnesia and was found wandering by the police in a London station (5135), and a sailor (5290), who is in prison for a very violent assault for which he has amnesia, yet with no history suggesting epilepsy.

Table III shows the distribution of the case material between groups 1 and 2 and the clinical diagnoses. It is seen that the neurotics fall exclusively into group 1 and the epileptics exclusively into group 2. The psychopathic patients are almost evenly divided, but there are too few of these patients for any significant factors to emerge. In subjects with post-traumatic states there is a strong tendency for those with mild head injuries to fall into group 1. Examination of many more patients is required before it is possible to investigate the relation between groups 1 and 2 and factors such as severity of injury and age at which the injury has been received.

There is, however, a clear correlation with the clinical diagnosis in the epileptic and neurotic groups, the most important point being that no habitual epileptic is found in group 1. In a case of doubtful diagnosis of epilepsy, therefore, if delta rhythms of voltage over 75 μ v. appear on over-breathing with a blood sugar level of above 130 mg. per cent. the probability is markedly increased that the patient is an epileptic, irrespective of the nature of the resting e.e.g.

Discussion

The results just described confirm the work of others that the appearance of slow rhythms on hyperventilation in certain people is greatly dependent on the blood sugar level and that there is a critical level at 120–130 mg. per cent. above which, in many cases (group 1), the response is stable.

The object of this investigation, as already stated, has been to find whether observation of the response to hyperventilation at raised blood sugar levels will help to single out any particular clinical condition since instability at fasting levels is found in both normal and a wide range of abnormal states. Instability on hyperventilation with blood sugar levels above 130 mg. per cent. has been found in all the overt epileptics in this series. There is unfortunately not sufficient data to indicate whether a person with a predisposition to epilepsy will react in the same way as the overt epileptics. If, however, the delta rhythms produced on hyperventilation in a given subject fail to occur when the blood sugar level is raised, the probability that this subject suffers from epilepsy is materially reduced.

Electro-encephalographic data has recently been put forward by Hill (1944) in support of the suggestion made in 1873 by Maudsley that a close relation exists between epilepsy and psychopathic aggression. If this relationship is accepted then the number of subjects in group 2 who have epilepsy in one form or another is increased and the probability that a group 2 response indicates epilepsy is correspondingly greater. Not sufficient is known of the group 2 cases who are not habitual epileptics or aggressive psychopathic persons, to indicate any relationship of their clinical condition to epilepsy with the exception of the subject in whom fits occurred during insulin treatment and the subject who fainted with incontinence as a child.

The need for performing an over-breathing test at raised blood sugar levels in investigating suspected epileptics is obvious.

The persistence of slow rhythms for more than 20 seconds after the cessation of hyperventilation is usually taken as an "abnormal" response. In the group 2 cases at blood sugar levels above 130 mg. per cent. the persistence is invariably less than 20 seconds. Instability on hyperventilation at these levels has been shown to have a significant meaning the expression of which, therefore, requires another standard. A better method of evaluation is the appearance of slow rhythms—mainly the 2–3 c./sec.—of high amplitude in any region of the cortex during the period of hyperventilation. If this standard is used it is not always necessary to over-breathe for 3 minutes as the appearance of the slow rhythms is sufficient to indicate instability.

It is not practicable, at least in wartime, to give 50 gm. of glucose to every patient before an e.e.g. examination, and it is not often possible for the patient to have a meal at a suitable time beforehand. It is better, therefore, to take the resting record and to over-breathe with the patient fasting and if delta waves are elicited to raise the blood sugar and repeat the over-breathing. Instability at fasting levels may eventually be shown to have clinical significance, and data is not lost by using the method described. Whenever instability on hyperventilation is found the blood sugar value must be estimated.

The criticism may be made that the suggested test is too simple in that not sufficient account is being taken of other physiological factors which may be of importance. However, it is a procedure which is possible for most e.e.g. departments, and it does assist in sorting the degrees of cerebral instability shown on over-breathing. It is only a beginning of correlating the clinical condition with the knowledge to be gained by studying the e.e.g. under various physiological stresses.

Summary

1. The response of the e.e.g. to hyperventilation at raised blood sugar levels has been studied in 71 adult patients who showed instability of cortical rhythms when fasting. The subjects include patients with epilepsy (22), neurosis (17), psychopathic personality (17), and post-traumatic states (9).

2. Two types of reaction have been observed; one (group 1) in which raising the blood sugar level inhibits the appearance of slow rhythms and another (group 2) in which, although there is a reduction in amount, slow rhythms are still elicited with a blood sugar value of 130 mg. per cent. or above.

3. There is a significant relation between the degree of abnormality of the resting e.e.g. and the group into which a case falls. Those cases with a normal or mildly abnormal resting e.e.g. tend to fall into group 1 and those with a more than mildly abnormal resting e.e.g. into group 2.

4. All the neurotics are found in group 1 and all the epileptics in group 2.

5. Instability of the e.e.g. on hyperventilation at blood sugar values above 130 mg. per cent. is significant and its presence in these circumstances markedly increases the probability that the patient is an epileptic.

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