in heterophoria a tendency for the visual axes to depart from parallelism, and the necessary co-ordination is effected by excessive use of the fusion faculty. When the muscles are fatigued this state of suppressed squint may become actual strabismus, and diplopia may be complained of.

It is obvious that heterophoria disturbs the co-ordination between accommodation and convergence, and that increased nervous energy is used up in each act of combined vision. In consequence fatigue will develop and cause asthenopia and headache. It is therefore essential that the error shall be corrected. I shall not here go into the details of the examination. We use the Maddox rod

and tangent scale for testing the muscle balance at infinity, and the Maddox wing test for measuring the error at reading distance.

Hyperphoria causes most trouble, but is not common. The most frequent defect is weakness of converging power, and this causes difficulty in reading and needlework. It is corrected by adding prisms base in to the near glasses, and such an addition is greatly appreciated by those who have convergence insufficiency.

REFERENCE.

¹Transactions of the Ophthalmological Society of the United Kingdom, vol. xlii, p. 127.

THE INFLUENCE OF INSULIN UPON ACIDOSIS AND LIPAEMIA IN DIABETES.

(A Preliminary Communication.)

BY

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THE effect of insulin in reducing the blood sugar of animals and of man has now been well established. Its similar action in an enhanced degree has also been found in cases of diabetes mellitus. In addition to reducing the high level of blood sugar in diabetes insulin has been shown to have the

percentage of the normal (Haldane²). The ketone bodies were estimated by the method of Van Slyke and Fitz,³ while the respiratory quotient and hourly metabolism were determined by the Douglas bag method. The lipaemia was determined comparatively by centrifuging the specimens of blood and noting roughly the degree of lipaemia of the plasma. Four stages were recognized: +++ where there was a definite layer of creamy fat above the plasma, ++ where there was marked opacity of the plasma, + where there was moderate opacity, and ± for a slight cloudiness.

The following cases are examples of those which have so far been investigated. It was considered advisable to make observations upon cases with a moderate degree of diminished bicarbonate reserve in order to have a comparison between normal people and diabetics without any such reduction, and those cases showing evidence of impending coma.

FIG. 1.

FIG. 1 (Case I).—B.R. = Bicarbonate reserve percentage (normal 100 per cent.). R.Q. = Respiratory quotient. Cal. = Calories per hour calculated from respiratory exchange. B.S. = Blood sugar percentage. B.K. = Blood ketone bodies in milligrams per cent. The respiratory quotient and the blood sugar percentage have been multiplied by one hundred in order to show them by means of the same scale of ordinates. Abscissae = time in minutes from commencement of observation. Patient fasting; weight 32.3 kilos. Insulin 10 units at point shown.

FIG. 2.

FIG. 2: Patient fasting; weight 32 kilos. Insulin 4 units at A. Glucose 16 grams at B.

FIG. 3 (Case II).—Letters and conventional signs as in Figs. 1 and 2. Patient fasting; weight 31.1 kilos. Insulin 10 units and glucose 20 grams at A. There was no lipaemia in this observation.

power of increasing the utilization of ingested carbohydrate. It is these facts which make the introduction of insulin of such importance in the treatment of moderately severe cases of diabetes.

In severe cases, however, other and more alarming disturbances are found. Lipaemia, increase of the ketone bodies in the blood, reduction of the bicarbonate reserve, together with hyperpnoea and mental disturbances, are all symptoms of great importance and frequently are forerunners of disastrous results. It seemed of importance, therefore, to ascertain how far insulin might remedy or prevent the occurrence of these conditions.

Methods.

The blood sugar, bicarbonate reserve of the whole blood, and the percentage of total ketone bodies in the blood were estimated, and where possible the hourly metabolism and respiratory quotient were determined. The blood sugar was estimated by the method of Folin and Wu,¹ the bicarbonate reserve was estimated by determining the carbon dioxide combining power of the blood at 40 mm. of mercury pressure of carbon dioxide, the amount found being expressed as a

CASE I.

F. H., a woman aged 24, was a case of severe diabetes that had been under observation from time to time for two years, giving a history of diabetic symptoms for three years. Her diabetic condition had progressed over numerous periods of exacerbation and remission, her carbohydrate tolerance diminishing from 67 grams a day to her present condition, in which 10 grams a day produce glycosuria. Observations were begun at 9 a.m. after sixteen hours' fasting, and were carried out under basal conditions as far as possible. The blood sugar before insulin was given was 320 mg. per cent., while the bicarbonate reserve was between 60 and 70 per cent. of normal (Fig. 1). Ten units of insulin were given and frequent examinations of the blood were made during the subsequent three hours. It will be noted that there was a steady decline of the blood sugar until it reached the level of 90 mg. per cent. Coincidentally there was an increase of the bicarbonate reserve from 59 per cent. to 91 per cent., and a decrease of the ketone bodies from 42 mg. per cent. to 8 mg. per cent. During this period the hourly metabolism varied but little, although the respiratory quotient showed a considerable change. The lipaemia rapidly disappeared. At the end of the observation the urine was free from sugar and ketone bodies.

On another day the patient was the subject of a second series of observations, which were carried out under similar basal conditions (Fig. 2). It was considered of importance to determine whether the administration of glucose with insulin influenced the response in any way. Therefore half a gram of glucose for each kilogram of body weight was administered shortly after insulin. Although the blood sugar was at approximately the same level as on the previous occasion, the bicarbonate reserve was not so much decreased. However, the results were similar to those already found. As on the previous occasion, lipaemia was present at the commencement and rapidly disappeared. The respiratory quotient was more constant, and showed a definite and gradual increase and decline after the administration of insulin and glucose. The blood sugar curve increased for a time, but at the end of one hundred minutes it had returned to its fasting level, and then declined still further. The decrease in the ketone bodies was most conspicuous, being reduced from 48 mg. to 6 mg. per cent. at the end of eighty minutes. As at the end of the previous observation, the urine was free from ketone bodies.

CASE II.

E. A., a woman aged 20, was admitted to the Royal Infirmary a fortnight previous to the observation suffering from thirst, polyuria, and emaciation of about nine weeks' duration. Two days after admission her blood sugar was 222 mg. per cent., and the urinary sugar 4.7 per cent. (105 grams in twenty-four hours). She showed only a moderate degree of acetonuria. Four days later she became sugar-free, but the acetonuria remained, although there were no symptoms suggestive of a severe acidosis. This observation (Fig. 3) showed results somewhat similar to those of Case I (Fig. 2).

CASE III.

J. I., a woman aged 30, was admitted to the Royal Infirmary having suffered from diabetes for eighteen months. The day after admission she developed mental symptoms, having hallucinations and delusions. A few hours later there was considerable hyperpnoea, and she became semi-conscious. The blood sugar at this time was 601 mg. per cent., and the bicarbonate reserve was only 40 per cent. of the normal. She was treated with insulin, glucose, and alkali (in the form of disodium phosphate). During the first twelve hours she received 40 units of insulin and 17 grams an hour of carbohydrate. The blood sugar steadily increased until at the end of twenty-four hours it amounted to 1,000 mg. per cent. (Fig. 4). A parallel increase of the bicarbonate reserve occurred; at the end of twenty-four hours it was 70 per cent. of normal, at the end of forty-eight hours 90 per cent., and at the end of seventy-two hours 4 per cent. above normal (104 per cent.). On the second day she received 80 units of insulin with 19 grams of carbohydrate an hour. On the third day 60 units of insulin with 15 grams of carbohydrate an hour. During this period the blood sugar fell from 1,000 mg. per cent. to 500 mg. per cent. On the fourth day she received 80 units of insulin with 1 gram of carbohydrate an hour. The blood sugar rapidly fell to 150 mg. per cent., and the urine was free from sugar. The insulin was reduced and the carbohydrate increased, with a rapid increase of the blood sugar but no appreciable diminution in the bicarbonate reserve.

Within twenty-four hours of the onset of the acute symptoms of acidosis and semi-coma the patient was quite conscious and all evidence of her acute crisis had passed away. During the succeeding days, however, her mental condition was far from normal, and she still had certain hallucinations and delusions, but these rapidly disappeared, and her condition continued along the usual course. It seems probable that this mental condition may have been due to organic changes in the central

nervous system, the result of the severe disturbance of cellular metabolism.

CASE IV.

Mrs. P., aged 44, had evidently been suffering from diabetes for a few months only, and was admitted to the Royal Infirmary in a state of diabetic acidosis verging upon coma. She was quite incoherent in her remarks, and did not appreciate her surroundings. There was considerable hyperpnoea

with tachycardia and great prostration. The blood sugar amounted to 390 mg. per cent., the ketone bodies in the blood to 62 mg. per cent., and the bicarbonate reserve was but 45 per cent. of normal (Fig. 5). The lipaemia was considerable. In view of the results obtained in the cases already outlined it appeared to us to be very important to determine whether insulin and glucose alone, without the administration of alkali, would have the same beneficial effect as was obtained in Case III. The alkaline reserve, ketone bodies, and blood sugar were estimated every four hours, and at these periods insulin and carbohydrate were given (Fig. 5). During the first twenty-four hours in hospital 120 units of insulin and 190 grams of carbohydrate were given. At first there was a slight rise in the blood sugar from 390 mg. per cent. to 440 mg. per cent. During the succeeding twenty hours there was a steady decline, until at the end of twenty-four hours it amounted to only 110 mg. per cent. The increase in the bicarbonate reserve followed almost a straight line from 45 per cent. to 89 per cent. of normal, the decrease of the ketone bodies following almost a parallel course. The lipaemia had disappeared at the end of ten hours.

The improvement noticed in the patient's condition during the first sixteen hours was most spectacular, and at the end of twenty-four hours she appeared practically normal. In spite of the large quantity of carbohydrate taken, the glycosuria during the first seven hours amounted to but 5 grams an hour, for the next twelve hours it averaged three-quarters of a gram an hour, and during the last five hours there was but a trace, the urine at the end of twenty-four hours being sugar-free.

In view of the results obtained in these cases it seems to be indicated that insulin and carbohydrates, when given together in sufficient amounts to patients with diabetic acidosis verging upon coma, have a most beneficial and indeed spectacular effect.* The rapid disappearance of the lipaemia and ketone bodies of the blood, and the return to normal of the bicarbonate reserve, clearly indicate the means whereby this improvement is brought about. In Case III the great increase in the blood sugar did not appear to have any deleterious effect—in fact we have reason to suppose that an adequate supply of carbohydrate is most important in the treatment of such cases, and that in view of the known deficiency of glycogenic function this supply must mainly be available in the form of sugar in the blood and tissues. If it be true that the acidosis in diabetes is the result of the imperfect oxidation of fat through the inability of the cells to use carbohydrate, such results as we

have obtained are quite to be expected.

It is noteworthy that the reduction of the blood sugar was not always accompanied by such an increase of the respiratory quotient as might be expected if the sugar had been burnt. Determination of respiratory metabolism in emotional subjects may not give a proper indication of the

*We wish especially to emphasize the importance of combining carbohydrate administration with the use of insulin in cases such as the above. We have evidence that the administration of insulin alone may increase the amount of acidosis present. This question is at present under investigation.

Fig. 4 (Case III).—Letters and conventional signs as in previous figures. Dotted line with crosses = insulin units per day. Total rectangles = carbohydrate ingestion grams per hour. Dark shaded rectangles = carbohydrate excretion grams per hour. Light rectangles = difference retained.

Fig. 5 (Case IV).—Letters and conventional signs as in previous figures. Dotted line with crosses = grams of carbohydrate taken. Dotted line with circles = insulin units administered. Rectangles = sugar excreted, grams per hour.

true respiratory quotient owing to irregularities of the breathing. Yet in such cases as the above there is another factor to be considered. The liberation of alkali in the blood consequent upon the removal of the ketone bodies would result in a compensatory retention of carbon dioxide. This might easily be sufficient in amount not only to mask any rise but even to produce a fall in the respiratory quotient. It will be noted in Fig. 1 that there is a conspicuous fall in the respiratory quotient at the time the increase of bicarbonate reserve is most rapid.

The above results form part of a larger scheme of research undertaken on behalf of the Medical Research Council.

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¹Folin and Wu: *Journ. Biol. Chem.*, 1920, vol. 41, p. 367. ²Christiansen, Douglas, and Haldane: *Journ. of Physiol.*, 1914, vol. 48, p. 244. ³Van Slyke and Fitz: *Journ. of Biol. Chem.*, 1917, vol. 32, p. 495.

TRAUMATIC PARAPLEGIA:

OBSERVATIONS ON CASES WITH REFERENCE TO TREATMENT AND PROGNOSIS.

BY

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THE object of this paper is to give an account of cases of paraplegia of traumatic origin with a view to establishing a rational treatment and prognosis. All the cases are collected together at the Queen Alexandra Hospital Home at Roehampton, and afford a unique opportunity for study.

It was rare before the war to meet a group of cases of uncomplicated traumatic paraplegia. The cases discussed in this report are all traumatic; all were young men when wounded, and their general health and strength at the time of the injury were apparently good. The belief is therefore warranted that most of the symptoms are purely the result of the spinal injury. It is possible, therefore, to draw conclusions as to treatment with reference to prognosis. In paraplegia following some particular disease this is not possible, since the pure picture of paraplegia is blurred in with the general symptomatology of the particular disease causing the paraplegia.

Types of Cases.

The number of cases studied was 56, and the average age at the date of injury 21. All the cases when first seen had been wounded for three years, and some for five or six years. Of the 56 cases 39 were of the complete lesion type at the level of the fourth to tenth segments; 17 of the incomplete lesion type, ranging from the eighth to the lower lumbar segments.

In the cases with a complete lesion two well marked types can be distinguished—those with flaccid paralysis (paraplegia in extension) and those with spastic paralysis (paraplegia in flexion). Both types have an equal degree of motor and sensory paralysis extending as high as the original level of the lesion, but in the flaccid type there is a complete absence of all tendon and skin reflexes (with the exception of the anal skin reflex, which in a few cases is present). The lower limbs lie quite motionless, wasted, and shiny. The spastic cases, on the other hand, show an exaggeration of the knee-jerks (the ankle-jerks vary, and are occasionally absent), an extreme degree of ankle and patellar clonus, and a double Babinski response. The limbs appear very irritable to small stimuli; stroking or blowing on the skin surface will generally lead to involuntary contraction, the thigh becoming flexed on to the abdomen. A slight degree of irregular wasting of one or both limbs is to be observed, and the motor and sensory loss is as complete as in the flaccid cases. In both types there is complete loss of voluntary control over micturition and defaecation.

The cases exhibiting an incomplete cord lesion also fall into two types—the spastic and flaccid. The spastic cases have brisk tendon reflexes with pronounced double Babinski toe reflexes and ankle clonus, and the abdominal reflexes are absent. In one case, however, both upper and lower abdominal reflexes are briskly present, the Babinski reflex also being very pronounced. A certain amount of irregular wasting of the calf and thigh muscles may be present. The power of voluntary movement of the lower limbs is considerable, especially after

adequate massage, but walking is generally difficult, since so much energy is expended in overcoming the spasticity.

In the flaccid cases either all reflexes in the lower limbs are absent, or the knee-jerk is just elicitable in one or both limbs. The knee-jerk, if present, is not altered by reinforcement; one smart tap will elicit it, and a series of taps with the patient's hands clenched, etc., do not alter its character. The wasting may be very considerable, especially in the calf muscles, but the thigh muscles may be only moderately wasted. Systematic massage can improve this wasting very noticeably, but the neurological signs (that is, tendon reflexes) do not alter.

Voluntary movement varies. Most patients can stand and walk with aid, the motive power appearing to come from the muscles of the pelvic girdle. The loss of superficial sensation in the lower limbs is of a very patchy and variable nature, the majority showing an irregular riding-breeches anaesthesia with some patchy analgesia over the feet. The loss of muscle and joint sensibility is generally great, and nearly all the patients who can walk can only do so by looking at their feet; they cannot walk in the dark.

The bladder and rectal functions show a varying degree of departure from the normal. The majority of patients are aware of the desire to pass water and can control the passing of it—provided the bladder is not too full or the weather not too cold. Occasionally retention occurs, and a catheter has to be passed or retained for a few days. Five cases have almost normal bladder control but complete faecal incontinence, whilst three have no bladder control but normal rectal control. Sexual impotence is invariable. Priapism is common, and often a most distressing and, if there be obstruction to the circulation by a tightly fitting rubber urinal, a highly dangerous complication.

The blood pressure is within normal limits in all, and there is no difference between the arm and the leg readings.

Special Symptoms in the Complete Type.

The symptoms now to be described are not as a rule found in the incomplete type of paraplegia.

Pain in the lower extremities is described as sharp, gnawing, gripping, burning, cutting, and is felt all down both legs; when very severe its onset is acute and there is a rise of temperature, though never above 101° in uncomplicated cases. There is no visible change of any kind in the physical signs. The patient is obviously in very acute pain, and is only relieved by hypodermic injections of morphine. A moderately severe attack is sometimes checked by aspirin, or better with salipyrin (gr. xx). The duration of these attacks is usually about twenty-four to forty-eight hours or less; if longer, some other factor is responsible, such as an old bed sore which has become septic, or renal colic. The patients themselves ascribe these attacks to a change in the weather. I confess myself sceptical on this point, but cannot offer any adequate explanation as to the mode of origin of these pains. The symptoms suggest some irritation of the sympathetic nervous system, especially the pains described as gnawing and gripping, and may have an origin in the sympathetic ganglia outside the cord. Whatever the cause, there is no doubt that these limb pains form a very definite part of the syndrome of the complete type of paraplegia. Nearly all the patients complain of a continual sensation of tingling in the lower extremities, but this is not described as painful.

Flatulence is a very common and occasionally an acutely painful complaint. Well marked generalized abdominal distension with ladder-like peristalsis is to be observed, sometimes so great as to suggest definite obstruction. As a rule there is no vomiting, but constant eructations of gas and the passage of flatus per anum. The very severe cases look ill, and present a toxic appearance suggesting uraemia. These cases are relieved by a single injection of pituitary extract (posterior lobe, 1/2 to 1 c.cm.). The slighter cases, with moderate abdominal distension and pain, are often strikingly relieved by injections of mx of 1 in 1,000 liquor adrenalin. hydrochlor., or by double doses by the mouth in ice-cold water. An enema, either simple or mixed with asafoetida, does not appear to relieve