Diabetic Acidosis: Prevention and Treatment

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Diabetic acidosis is one of the most dramatic of medical emergencies. The patient who develops this condition may within a few days pass through the successive stages of dehydration, ketosis, coma and death. This progression of events can be entirely prevented if the condition is recognized and treated in time.

The prevention of diabetic acidosis depends on thorough understanding of diabetes by both the patient and his physician. This complication may threaten any diabetic, under the stress of an acute infection, or other illness, trauma or surgical operation. Under these circumstances, insulin may be needed in large dosage, even in cases previously treated successfully with diet alone. If this need is not met, acidosis may result. Both the physician and the patient must be alert to the danger; if the proper steps are taken, acidosis will not occur. The patient should be encouraged to telephone his physician regarding even minor illnesses. He should be taught to test his urine every four to six hours during an illness; heavy glycosuria will warn him of impending trouble. Additional doses of quick-acting (regular or crystalline) insulin, the amount depending on the degree of glycosuria each time will usually prevent the occurrence of acidosis. A dosage schedule commonly recommended is: 20 units for a red test, 15 units for orange, 10 for brown, and 5 for green. A smaller amount should be employed for a child, or for the adult who is subject to hypoglycemic reactions.

Most patients admitted to the hospital in severe acidosis have failed to seek medical advice during the early stages of this disorder. Some of these have not previously known that they had diabetes. The incidence of such cases can be reduced only by education of the public regarding the symptoms of diabetes, and by the practice of periodic health examinations. Other patients are those with treated diabetes who have become increasingly careless in following their diabetic regime. Such patients neglect the diet, stop testing the urine and allow appointments with the physician to lapse. Often a trifling infection upsets their precarious balance, and when vomiting sets in, they may commit the final error of omitting the essential insulin injections. Since many of these patients, after recovery from acidosis, make certain that it never occurs again, it is probable that the initial episode was due in part to a failure to appreciate the danger. Thus education of the patient must play an important role in preventing this complication. The physician, by taking pains to give the patient and his family thorough instruction in diabetes, and by establishing and maintaining a cordial and sympathetic relationship, can greatly reduce the likelihood of this complication.

DIAGNOSIS

Diabetic ketosis is easily recognized by finding acetone in the urine or by detecting the odor of acetone on the breath. Ketosis of slight degree is a common occurrence when diabetes is only mildly out of control, particularly in cases of unstable or "brittle" diabetes. Hence, the presence of acetone in the urine or on the breath need not of itself cause alarm, although it should definitely put the physician on guard. The *absence* of ketosis today is of course reassuring, but affords no guarantee that it will not be present in a serious degree tomorrow. It is important to realize that diabetic acidosis has an insidious nature, and that the patient does not appear ill until the process is well advanced. It is therefore the task of the physician to evaluate the diabetic state of his patient each time he is consulted and especially when the patient calls him for some other illness. A history of increased volume and frequency of urination, of thirst and weakness, along with the finding of much sugar and acetone in the urine indicates the presence of ketosis which could quickly become serious. If in addition the patient reports anorexia, vomiting and abdominal pain; and if the physician notes a parched tongue, air hunger and drowsiness, a dangerous state of acidosis must be present.

Further laboratory tests are often helpful in evaluating the patient's diabetic status, although in practice the immediate decision as to the plan of treatment will be governed by the patient's appearance. In general, the higher the blood sugar, the more alarming the situation.

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A blood sugar of 250 mg. is usually reassuring, but it should be remembered that occasionally diabetic coma is encountered with the blood sugar no higher than this. A depressed plasma carbon dioxide combining power, on the other hand, is almost always significant, and a positive serum acetone test[1] is a sure indication of a serious degree of ketosis.

If the diabetic patient is unconscious, a special problem is presented. Is the coma due to hypoglycemia, or to acidosis, or to some condition unrelated to diabetes? A history of sudden onset (in less than two hours) combined with the presence of profuse sweating justifies immediate treatment for hypoglycemia. A history of illness for more than twenty-four hours culminating in coma, combined with the presence of air hunger and dehydration, makes the diagnosis of diabetic coma almost certain. In such a situation treatment with insulin should be started without waiting for confirmatory laboratory reports.

TREATMENT

The milder degrees of ketosis may be treated safely at home. The patient is instructed to take his usual dose of insulin, and in addition, to take small doses of quick-acting insulin before meals and at bed-time according to the degree of glycosuria. If he has an illness which makes it difficult for him to remain on his usual diet, he is instructed to take small amounts of liquids and soft solids every hour or two. The physician should of course maintain close contact to assure himself that these orders are being carried out and are resulting in satisfactory control. If the illness is such as to interfere with an adequate oral intake, or if the physician has any doubt about the ability of the patient or his family to follow the instructions, it is wise to hospitalize the patient so that fluids may be given intravenously and closer supervision may be maintained.

For patients with a severe degree of acidosis, immediate hospitalization is imperative. The situation then calls for prompt and vigorous treatment, and for the full-time attention of the physician until recovery is assured. Any delay in initiating treatment may prove fatal; hence the first dose of insulin, 50 to 100 units, should be given as soon as the diagnosis is reasonably certain. A solution of isotonic sodium chloride should also be given by venoclysis as soon as possible. Blood should be drawn at once for determination of the blood sugar and the serum CO_2 content. (Other blood tests, such as the blood *p*H, hematocrit, nonprotein nitrogen and serum chloride may be helpful; and if the laboratory has a flame photometer the serum sodium and potassium should be ascertained.) In addition to these measures, a Foley catheter should be placed in the bladder if the patient is unconscious or unable to void. An electrocardiogram taken at this point may be of help later in the recognition of a potassium deficiency. It is well to start a chronological chart on which is recorded at hourly intervals the vital signs, the fluid intake and output, the laboratory tests and treatment, so that the patient's progress may be more clearly followed.

Another procedure which is usually recommended at this time is gastric lavage, as the patient in acidosis often has a dilated, atonic stomach which is distended with secretions and a large amount of partly-digested blood. He is vomiting small amounts frequently, and is intensely nauseated and distressed; his pulse may be rapid and thready. Gastric aspiration and lavage will often produce marked relief of these symptoms and a gratifying improvement in the pulse and blood pressure. Furthermore, the patient will be able to accept oral feedings at an earlier hour if this procedure is performed.

When these preliminary measures have been completed the physician may now take time to review the situation and evaluate the patient's condition. A history and a physical examination are required for recognition of infection or other complicating conditions, and for evaluation of the severity of the diabetic state. It is important to realize that fatalities occasionally occur in cases that do not appear seriously ill on admission to the hospital.[2] It is for this reason that constant watchfulness is essential in the treatment of each case. It should be kept in mind that acidosis may simulate an acute abdominal emergency. However, unless there are cogent reasons for believing that there is a surgical emergency, operation should be postponed, because usually the symptoms and signs disappear as the diabetic state is corrected.

At this point the physician is faced with the question: How much insulin should I give, and how often should I give it? It is impossible to give a dogmatic answer to this question. A recent suggestion has been made[3] that the first dose be equal in units to one-half the blood sugar level; (for example if the blood sugar is 1,000 mg., 500 units would be given at once). A second dose would be given four hours later, its size depending on the response of the blood sugar in the interval. However, most physicians will prefer to give an hourly dose of insulin, gauging the size of the dose by the change in blood sugar level, the degree of glycosuria and ketonuria, and the patient's general condition. For patients who are only moderately ill, 50 units every hour or two should be sufficient; for those who appear

acutely ill, and especially for cases in which the blood sugar is over 700 mg. per 100 ml., a dose of 100 to 200 units every hour is advisable. It may be advisable to give half of each dose intravenously, particularly when a state of shock is present. The dosage recommended for children is not greatly different from that for adults; but infants may be expected to respond to considerably smaller doses, such as 10 to 20 units each hour. Using the above dosage schedule, the blood sugar level will usually begin to fall in two or three hours, and will thereafter fall quite steadily. Occasionally a case is encountered in which the expected fall in blood sugar fails to take place. In this event the dosage schedule should be revised upwards, perhaps doubled, until a definite lowering of the blood sugar has been attained. As the blood sugar reaches a range that is no longer alarming, let us say 250 to 300, the size of the doses should be markedly reduced, and the interval between injections lengthened.

A recent interesting study[4] has cast some doubt on the value of huge doses of insulin, and suggests that there is no appreciable reduction in mortality or increased speed of recovery when large doses are administered instead of moderate ones. However, until this work is fully confirmed, I shall continue to advocate large doses for the patient with a very high blood sugar or whose blood sugar and general state have not improved within a reasonable time.

It is recommended that the blood sugar be checked every two or three hours in the first twelve to twenty-four hours. But sometimes the physician must depend upon the urine test, which is a much less reliable guide. The serum acetone test, as suggested by Duncan[1] may be valuable; a decrease in the degree of ketonemia foreshadows the disappearance of the insulin resistance which is usually present at the beginning of treatment. When the serum acetone test becomes negative, insulin should be administered with caution to avoid serious hypoglycemia.

There is still considerable disagreement about the ideal fluid to be employed intravenously in the early hours of treatment. It is my impression that most of the experts in this country administer isotonic sodium chloride solution. A few add sodium lactate or bicarbonate to this solution, and a few prefer more dilute solutions. Many continue to give glucose, although the arguments against its use are to me quite convincing. Briefly, these arguments are: (1) The blood already contains an excess of sugar, and additional glucose raises the level and increases the dehydration of the cell. (2) Intravenous glucose, by raising the blood sugar, diminishes the value of the blood sugar test in following the progress of treatment. (3) Intravenous glucose with insulin hastens the withdrawal of potassium from the blood and increases the risk of fatal hypokalemia. (4) Careful studies[5] have indicated that patients given glucose in the early hours of treatment have a higher mortality and a slower recovery rate.

Although the use of glucose in the early hours of treatment appears to be contraindicated, the objections to its use disappear as the blood sugar approaches normal; indeed, it then becomes a highly desirable part of treatment, as it provides calories and protects the patient from hypoglycemia.

The total quantity of fluid administered by venoclysis will vary, depending on the size of the patient and the degree of dehydration. Large amounts of saline can produce edema, particularly in the elderly and in those with cardiac or renal disease. While most authorities advise rapid administration of the first liter or two of saline solution to combat shock, I believe that it is wiser to administer it at a rate which can be maintained for many hours without overloading. If shock is present on admission, or if the blood pressure drops toward shock levels during treatment, whole blood or plasma may be given to support the circulation. Other supportive measures such as epinephrine, caffeine and digitalis are occasionally indicated. Perhaps the most satisfactory fluid replacement therapy is that which can be given orally rather than intravenously. Most acidotic patients are unable to retain feedings at first, so that oral feeding must be delayed for a few hours, and then cautiously attempted as nausea subsides. Small amounts of broth, milk, fruit juices and oatmeal gruel may be given at frequent intervals, providing easily-digested food containing some calories and a considerable amount of potassium.

Replacement of potassium, to avoid the dangers of potassium deficiency during recovery, has become an established part of the therapy of diabetic acidosis. It should be remembered that most untreated acidotic patients have a normal or slightly elevated serum potassium because of the large amount of potassium escaping from the cells.[6] During the course of treatment, the potassium level quite regularly falls as potassium migrates back into the cells. If the serum potassium falls below the level of 2.5 mEq./L. it is a sign of danger. Clinically, potassium deficiency should be suspected if the patient develops muscular weakness, or feeble or gasping respirations; or cardiac disturbances[7] such as the appearance of murmurs, a gallop rhythm, tachycardia and a fall in blood pressure, particularly the dia-

stolic blood pressure. The electrocardiogram may give valuable evidence of potassium depletion,[8] showing progressive flattening of the T waves and lengthening of the Q-T interval.

This complication will rarely occur in the patient who is able to retain potassium-rich oral feedings starting within a few hours of admission. But in cases in which there is repeated vomiting or prolonged coma the danger of death in hypokalemia is very real. Potassium salts should therefore be added to the intravenous infusion as soon as it is established that the patient has an adequate urine output—not sooner, because of the risk of producing potassium intoxication in the oliguric patient. Sterile ampules of potassium chloride are available commercially, and may safely be given in a dose of 1 or 2 gm. (13.8 to 27.6 mEq.) in each liter of the clysis fluid. Even larger amounts, up to 10 gm. per liter (138 mEq.) may be administered when the chemical and clinical evidence clearly indicates the need.[6]

It has also been recommended that potassium salts be given by mouth as soon as the patient is able to retain oral medication. In one series[3] the *average* dose of orally administered potassium dibasic phosphate was 18.6 gm. (214 mEq. of potassium) and others have recommended potassium chloride 1 to 2 gm. (13.8 to 27.6 mEq.) by mouth every one to two hours. Various studies have shown that a large percentage of the administered potassium is retained, and that with adequate potassium therapy, the serum potassium is prevented from falling to critically low levels.

SUMMARY

Methods of prevention of diabetic acidosis are discussed, stressing thorough education of the patient, the maintenance of a good doctor-patient relationship, and the recognition of the earlier stages of ketosis. The treatment of severe acidosis is discussed with emphasis on prompt initiation of treatment, the need for constant attendance, and the importance of simple laboratory procedures such as blood sugar determinations in following the patient's course.

SUMMARIO IN INTERLINGUA

Acidosis Diabetic: Prevention e Tractamento

Es discutite methodos del prevention de acidosis diabetic. Le factores sublineate como specialmente importante include le detaliate education del patiente, le mantenentia de bon relationes personal de medico e patiente, e le recognition del precoce phases de cetosis. Le tractamento de sever acidosis es discutite. Le punctos hic sublineate include le importantia de prompte initiation del tractamento, le necessitate de constante surveliantia, e le valor de simple technicas laboratorial in sequer le curso clinic del patiente. Iste technicas include per exemplo le determination de sucro sanguinee.

REFERENCES

[1] Duncan, G. G., and Gill, R. J.: Clinical value of a simple qualitative test for plasma acetone in diabetic coma. Diabetes 2:353-56, 1953.

[2] Harwood, R.: Diabetic acidosis, results of treatment in 67 consecutive cases. New England J. Med. 245:1-9, 1951.

[3] Crampton, J. H., Mellinger, G. W., and Palmer, L. J.: Potassium in the treatment of diabetic coma. Diabetes 2:1-5, 1953.

[4] Smith, K., and Martin, H. E.: Response of diabetic coma to various insulin dosages. Diabetes 3:287-94, 1954.

[5] Franks, M., Berris, R. F., Kaplan, N. O., and Myers, G. B.: Metabolic studies in diabetic acidosis. 1. The effect of the early administration of glucose. Arch. Int. Med. 80:739-62, 1947.

[6] Martin, H. E., Hillier, P., and Wertman, M.: Potassium deficits in diabetic acidosis with particular reference to problems in therapy. Proc. Am. Diabetes Soc. 10:161-78, 1950.

[7] Frenkel, M., Groen, J., and Willebrands, A. F.: Low serum potassium level during recovery from diabetic coma, with special reference to its cardio-vascular manifestations. Arch. Int. Med. 80:728-38, 1947.

[8] Martin, H. E., and Wertman, M.: Electrolyte changes and the electrocardiogram in diabetic acidosis. Am. Heart J. 34: 646-62, 1947.