MEDICAL PRACTICE

*Clinical Topics***Intravenous insulin infusion in diabetic emergencies**

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Continuous intravenous insulin and dextrose infusions were used in managing various diabetic emergencies. Standard and constant rates of insulin and dextrose infusion resulted in satisfactory control of blood glucose concentrations during labour, after major surgery, and in patients recovering from ketoacidosis (average insulin infusion rates 1, 2, and 3 U/h respectively). Higher infusion rates were used to correct or prevent ketoacidosis in pregnant diabetic women who had received steroids and sympathomimetic agents.

The infusion method is simple, reliable, and flexible, and may help to simplify management of diverse types of diabetic emergencies.

Introduction

The management of various diabetic emergencies is confusing because of various regimens recommended by different authorities. The recent introduction of continuous low-dose insulin infusions in the management of diabetic ketoacidosis has greatly simplified treatment of this condition. A standard insulin infusion rate is generally effective irrespective of initial blood glucose values,¹ but if the response to treatment is not satisfactory the infusion rate may be changed and a new serum insulin concentration is rapidly achieved.

We have extended the use of continuous insulin infusions to other diabetic emergencies, in which patients cannot eat and need intravenous treatment. Hitherto a sliding scale of subcutaneous insulin four to six hourly has been used, the dose being determined by results of blood or urine tests. Nevertheless,

this regimen often results in poor control of blood sugar concentration. We aimed at simplifying management of diabetes by using standard infusion rates of insulin and dextrose. We applied this technique during recovery from ketoacidosis, after major surgery, during labour, and in other conditions of severely uncontrolled diabetes due to the administration of steroids or sympathomimetic agents.

Patients, methods, and results

The regimen was a continuous infusion of soluble or Actrapid (neutral insulin injection) insulin given by an infusion pump, the syringe containing 1 unit of soluble insulin to 1 ml 0.9% saline without albumin, and a continuous infusion of 5% dextrose, usually at 1 litre every eight hours (6 g dextrose hourly). Patients recovering from ketoacidosis were given potassium 5 mmol (mEq) hourly in addition. The blood glucose concentration was measured every two to four hours. When the blood glucose concentration rose the infusion rate of insulin was increased by 0.5-1 unit hourly. Once the patient could eat he was given his normal morning or evening dose of insulin. Thirty minutes later he was given 40 g carbohydrate as a small meal. When this had been consumed the insulin and dextrose infusions were stopped.

Four groups of patients were treated.

Group 1—Eighteen patients were treated after correction of diabetic ketoacidosis (mean initial blood glucose concentration $40.8 \pm \text{SD } 18.5$ mmol/l (735.1 ± 333.3 mg/100 ml); range: 23-102 mmol/l (414-1837 mg/100 ml)). When the blood glucose concentration had decreased below about 10 mmol/l (180 mg/100 ml; range: 6-14 mmol/l (108-252 mg/100 ml)) but before the patients were ready for food, insulin infusion (3 U/h) was continued for a mean of 13 hours (range 7-22), and steady blood glucose concentrations (mean 7.3 ± 3.1 mmol/l (131.5 ± 56.0 mg/100 ml)) were maintained. One technical failure in this group occurred because the infusion pump was switched off. Another patient relapsed when receiving this regimen and was subsequently found to have severe thyrotoxicosis. In both instances control of diabetes was regained.

Group 2—Fifteen diabetics were treated postoperatively. Insulin and breakfast were omitted on the morning of the operations. During the operations the anaesthetists infused as much dextrose as they thought was necessary. The operations were: five lower-segment caesarean sections; two gastrectomies; two cholecystectomies; two

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amputations; a mastoidectomy; a laparotomy; a hysterectomy; and a rib section. The dextrose and insulin infusion was started when the operation was finished. Insulin infusion (2 U/h) was given for 6-14 hours (mean 9.6) and steady blood glucose concentrations (mean 7.2 ± 3.8 mmol/l (130.0 ± 68.5 mg/100 ml)) were maintained. One technical failure occurred in this group, again because the insulin pump was switched off by mistake.

Group 3—Twelve diabetic women were treated during labour. Labour lasted 8.1 ± 3.0 hours and the blood glucose concentration was maintained at a mean of 4.9 ± 2.0 mmol/l (88.3 ± 36.0 mg/100 ml). The infusion rate varied from 0.5-3 U/h, but was usually at 1 U/h.

Group 4—Four pregnant diabetics developed premature contractions and were treated with both intramuscular dexamethasone (4 mg eight-hourly) to promote lung maturity and an intravenous sympathomimetic agent to reduce contractions. One such patient whose diabetes was well-controlled was on an insulin infusion pump as dexamethasone was being administered. She was given salbutamol 1.2 mg/h and rapidly became ketoacidotic requiring large doses of insulin by infusion. Figure 1 shows the details of her blood glucose concentrations and insulin requirement. When the contractions abated salbutamol was gradually withdrawn and the insulin requirement decreased. The contractions recurred while control of diabetes was good, and salbutamol was restarted at 0.6 mg/h. We anticipated the increased need for insulin by increasing its infusion rate immediately from 4 U/h to 20 U/h and later to 32 U/h. Control of diabetes was thus maintained without ketoacidosis (fig 2). Of three further patients given intravenous sympathomimetic agents, one required 10 U/h to correct ketoacidosis that had developed after salbutamol 0.4 mg/h had been given in another hospital, a second also needed 10 U/h to maintain good control of blood glucose concentration during infusion of salbutamol 1.6 mg/h, and a third was given isoxsuprine 60 mg/h and needed insulin at 8 U/h.

Discussion

Compared with older regimens for the management of diabetic emergencies the dextrose and insulin infusion regimen is simpler and more flexible and reliable. It is a logical extension of modern management of diabetic ketoacidosis. Standard and constant rates of insulin infusion resulted in satisfactory blood glucose concentrations in diverse conditions. Insulin infused at constant rates was effective in managing patients recovering from diabetic ketoacidosis (3 U/h), those who had undergone operation (2 U/h), and in diabetic women in labour (1 U/h). The insulin infusion rate seldom needed to be changed. In patients who had undergone operation the blood glucose value was maintained at concentrations that reflected the initial postoperative values. Since some of these initial postoperative values were quite high,

FIG 1—Blood glucose concentrations (open circles) and insulin dosage (closed circles) in a pregnant diabetic woman who became ketoacidotic during first infusion of salbutamol to control premature contractions.

Conversion: SI to traditional units—Blood glucose: 1 mmol/l $\approx$ 18 mg/100 ml.

FIG 2—Blood glucose concentrations (open circles) and insulin dosage (closed circles) in a pregnant diabetic woman during second salbutamol infusion (see fig 1).

it might have been better to start the dextrose and insulin regimen before the operation, continuing it during and after the procedure, and we now follow this course.

The problems of diabetic control when insulin resistance develops after administration of steroids or intravenous salbutamol have been greatly reduced by using insulin infusions. When steroids or sympathomimetic agents are given to pregnant diabetics to enhance lung maturation or delay labour hyperglycaemia with ketoacidosis may rapidly ensue,² and higher insulin doses may be needed than in diabetic ketoacidosis, when 6 U/h is usually adequate. After steroids insulin infusion is started as soon as blood glucose concentration begins to rise, but when intravenous salbutamol is given it is wise to start the insulin infusion at the same time (fig 2).

Good control of diabetes, which is essential during pregnancy, should also be maintained throughout labour.^{3,4} From 1969-72 it was our policy to use subcutaneous injections of insulin during labour. In 54 diabetic patients in labour the mean blood glucose concentration was 7.1 ± 3.2 mmol/l (129.1 ± 58.2 mg/100 ml). Control of diabetes was improved from 1973 with the introduction of continuous intravenous dextrose and insulin infusions, and in 38 diabetic women in labour the mean blood glucose concentration was 5.5 ± 2.5 mmol/l (99.1 ± 45.0 mg/100 ml). Nevertheless, insulin infusion rates were not standardised. This was unnecessary, especially if the dextrose infusion had been kept constant—for example, with an IVAC pump excellent control can be achieved with a dextrose and insulin regimen (insulin at 1 U/h) requiring only small and infrequent changes in the rate of insulin infusion. In the last 12 diabetic labours the mean blood glucose was 4.9 ± 2.0 mmol/l (88.3 ± 36.0 mg/100 ml).

Intravenous dextrose and insulin infusions are effective in the management of diabetic emergencies. The method failed in only two out of 49 cases, when the infusion pump was accidentally switched off. While such intravenous infusion systems are simple in practice, they do not obviate the need for good nursing care and rigorous observation as with all medical emergencies.

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