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EFFECTS OF INTRAVENOUS GLUCOSE ON BLOOD POTASSIUM IN CATTLE

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ABSTRACT

The aim of this study was to confirm whether a rapid intravenous glucose administration can lead to a significant drop in blood potassium levels in cattle. For this study, seven cattle were used according to internationally recognized guidelines for animal welfare. Glucose at a dose of 1 g.kg^{-1} body weight was administrated intravenously and then blood samples were taken before and 0.5, 1, 2, 4, and 6 hours after administration of glucose for measurement of potassium and glucose blood concentrations. For statistical analysis of glucose effects on both glucose and potassium levels one-way analysis of variance (ANOVA) for repeated measures was used. ANOVA showed a strong significant effect of the glucose administration on plasma glucose levels ($P < 0.001$). The glucose administration resulted in a mean plasma increase from 4.2 mmol.l^{-1} to 21.2 mmol.l^{-1} within the first minutes after the administration followed by a steady decrease back to the initial values. In contrast, ANOVA showed no significant effect of the glucose administration on plasma potassium levels. In conclusion, the glucose does not have a potassium-lowering effect when administered in a single large intravenous dose.

Key words: cattle; glucose; potassium

INTRODUCTION

Potassium is recognized as an essential nutrient in animal nutrition. It is the third most abundant mineral element in the animal body and the main ion of the intracellular fluid. Most of the total potassium in the body is located in the muscle tissue [6]. The most significant role of potassium is in relation to nerve innervation and muscle excitability, and it is also involved in carbohydrate metabolism [17]. In monogastric animals, higher secretion rates of insulin after a meal largely prevent food-induced increases, not only in plasma glucose but also in plasma K^+ concentrations, because both are taken up by the skeletal muscle cells under the influence of insulin. Cellular K^+ uptake into skeletal muscle cells was stimulated via an insulin-dependent increase in Na/K pump activity [4]. A rise in blood glucose concentration in response to intravenous glucose infusion results in a commensurate release of insulin from the pancreas, which acts to clear glucose by insulin-sensitive tissues to pre-infusion levels. The clearance rate of glucose from blood depends on non-insulin-dependent glucose clearance, the amount of insulin released from the pancreas, and the peripheral response to insulin [8]. The glucose requirements of the dairy cow are dominated by the necessity of the mammary gland for milk synthesis. With greater milk yield comes larger re-

quirements for glucose, which is mainly met through glucose synthesis in the liver [19]. An interesting relationship between hypokalaemia, insulin imbalances and hyperketonaemia was found in high-yielding dairy cows whereby changes in glucose homeostasis and hypokalaemia might, according to the researchers, be a contributing factor to the pathogenesis of abomasal displacement resulting from a decrease in abomasal tone [22]. On the contrary, the glucose administration can be also used in hyperkalaemic conditions in animals. Electrolyte imbalances such as hyperkalaemia are also common in diarrheic calves and can result in skeletal muscle weakness and life-threatening cardiac conduction abnormalities and arrhythmias [20]. It is well known that restoration of potassium homeostasis in diarrhoeic acidemic calves can be achieved by rehydration and alkalinization using intravenous solutions containing sodium bicarbonate [13]. However, a combined administration of insulin and glucose is a well-established treatment for hyperkalaemia [23]. It was hypothesized that intravenous administration of a glucose-containing solution induces endogenous insulin release and thereby exerts a potassium-lowering effect. This might be especially of relevance in the initial treatment of affected calves, where treatment objectives focus on the rapid correction of hyperkalaemia, hypoglycaemia, and profound acidemia [5]. This research question is also of interest because administration of glucose containing infusion solutions to diarrheic calves that require intravenous fluid therapy is popular in ambulatory field practice. Intravenous glucose is administered to counteract negative energy balance and provide a readily utilizable energy source when calves are housed in cold ambient conditions [1]. Although the administration of intravenous dextrose is among the most commonly recommended treatments for hyperketonaemia in postpartum dairy cattle, the evidence for its use and a comparison of its respective metabolic consequences alone or in combination is largely unstudied [15].

The purpose of this study was to confirm whether a rapid intravenous glucose administration can lead to a significant drop in blood potassium levels in cattle.

MATERIALS AND METHODS

The group of the experimental animals consisted of five heifers and two Holstein-Friesian dairy cows which were admitted to the Clinic for treatment of various health disorders. They were clinically healthy at the time of the study. Blood was collected by venepuncture of the jugular vein before, and 0.5, 1, 2, 4, and 6 hours after the administration of glucose. Each animal was given one gram of glucose per kg body weight, which resulted in 1000 ml of 40 % glucose solution for a 400 kg cow on maximum infusion speed. The average time of administration was 25 minutes, approximately. The plasma concentrations of glucose were assayed with the kits supplied by Randox Laboratories Ltd. on spectrophotometer Alizé (Lisabio, France). The serum potassium concentrations were determined by the flame AAS method (Perkin Elmer Analyst 100).

For statistical analysis of glucose effects on both glucose and potassium levels, one-way analysis of variance (ANOVA) for repeated measures was used.

Ethical statement

All procedures concerning the animals were performed in compliance with the national guidelines for animal care.

RESULTS

The glucose administration resulted in a mean plasma increase from 4.2 mmol.l^{-1} to 21.2 mmol.l^{-1} within the first minutes after the administration. From the peak in plasma glucose at 30 minutes, there was a steady decrease in the plasma glucose concentration to 3.36 mmol.l^{-1}. ANOVA showed a strong significant effect of the glucose administration on plasma glucose levels ($P < 0.001$). The serum potassium concentrations tended to decrease within the first hour after the glucose injection and then there was a trend towards a steady increase in potassium serum concentration. ANOVA showed no significant effect of the glucose administration on serum potassium levels (Table 1).

Table 1. Mean plasma glucose and serum K (x ± SD) before and after glucose administration

Collection time (h)	Glucose (mmol.l^{-1})	Potassium (mmol.l^{-1})
0	4.22 ± 0.59	3.56 ± 0.74
0.5	21.2 ± 5.02	3.41± 0.74
1	15.4 ± 3.97	3.30 ± 0.75
2	8.41 ± 3.05	3.52 ± 0.83
4	3.83 ± 0.66	4.03 ± 0.74
6	3.36 ± 1.39	3.75 ± 0.96
ANOVA	P < 0.0001	P > 0.05

DISCUSSION

Potassium is one of the major elements and has an important role together with other elements such as sodium, chlorine and bicarbonate ions. Together they control the acid-base balance and the osmotic regulation of fluids in the body [17] as serum potassium serves as a regulator of aldosterone secretion in which high serum levels of potassium increases plasma aldosterone levels [2]. The most abundant role of potassium is in relation to nerve and muscle excitability, and is also involved in carbohydrate metabolism [17]. Potassium deficiency is rather rare in farm animals under normal conditions, due to a high concentration of potassium in plants, for example, 25 $g.kg^{-1}$ DM in grass. Symptoms of deficiency in calves given milk replacement low in potassium includes severe paralysis [17]. In general, hypokalaemia will increase the membrane potential, resulting in a hyper-polarization block causing weakness of muscles or paralysis, ileus, cardiac arrhythmias, rhabdomyolysis and renal dysfunction [7, 14]. Hypokalaemia is commonly the result of gastrointestinal losses from either diarrhoea or vomiting or excessive renal losses due to diuretics, overload of mineral-corticoids or renal tubular acidosis [14] but also from excessive rapid bicarbonate administration, insulin with glucose administration or catecholamine release [12]. As glucose is used very frequently in the treatment of many bovine diseases it was essential to test the hypothesis of the *in vitro* study [22], as it was stated that when glucose was administered in a single rapid dose of (500 ml, 40 %) the serum concentration of potassium decreased strongly. It was previously shown that an intravenous bolus of glucose led to an increase in insulin concentrations with a peak approximately 10 min after the administration and to a nadir in NEFA concentrations approximately 45 min after the treatment with a return to baseline concentrations within two hours [16].

There is concern that the standard treatment of 500 mL of 50 % dextrose is excessive and may have detrimental effects, including the causation of electrolyte and mineral imbalances following an intravenous bolus infusion [9]. In particular, the physiological decline in plasma phosphate concentration due to an insulin-dependent intracellular shift is of interest as clinical hypophosphatemia may be associated with muscle weakness and recumbency [10]. Bolus infusion of 500 mL of a 50 % dextrose infusion lead to an average decline in plasma phosphate ranging from 1.1 to 1.5 $mg.dl^{-1}$ within 60 min after bolus infusion in 2 separate studies [11]. A prior investigation has demonstrated that the cellular uptake of glucose, potassium, and phosphorus, when stimulated by insulin, operates independently and is not interrelated. There are specific resistance mechanisms in place that decouple impaired glucose disposal, as seen in diabetic patients, from potassium uptake, and vice versa [18]. In an experimental study involving rats, it was observed that even a brief period of potassium deficiency resulting from a potassium-deficient diet (which led to only a 9 % reduction in plasma potassium concentration) caused an 80% decrease in insulin-induced cellular potassium uptake. In contrast, glucose disposal rates remained unaffected [3]. The results presented in this study did not reveal a serum potassium-lowering effect of intravenous glucose administration. However, most of the experimental animals had the serum potassium levels slightly below the physiological range (4.0–5.5 $mmol.l^{-1}$) prior to the glucose administration. The absence of changes in potassium concentrations after treatment with 500 mL of 40 % glucose is consistent with the findings in the study with intravenous administration of 500 ml of 50 % dextrose by Mann et al. [15]. This finding was confirmed in a study on calves where an intravenous bolus of 0.3 g of glucose per kg of BW administered over a period of 1 min resulted in an increase of serum insulin concentrations but did not affect potassium responsiveness [21].

CONCLUSIONS

Based on the results of this study, it can be concluded that a single intravenous administration of the glucose is not associated with a severe risk of metabolic and health impairment in cattle due to the significant drop in blood potassium. Thus, the use of the glucose in treatment of an energy deficiency in cattle can be further recommended.

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