SHORT COMMUNICATION

Effect of intravenous sodium lactate on renal tubular reabsorption of phosphate in man

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Summary

1. The effects of sodium DL-lactate and sodium chloride (2.5 mg/kg as 865 mmol/l solutions given by intravenous infusion over 20 min) on the renal tubular reabsorption of phosphate have been compared in five normal adults.

2. Sodium lactate produced a marked but transient increase in urinary phosphate excretion due to a reduction in net renal tubular reabsorption of phosphate; the mean value of the maximum rate of renal tubular reabsorption of phosphate/unit of glomerular filtration rate (T_{mp}/GFR) decreased from 1.14 to 0.82 mmol/l.

3. This effect was not due simply to expansion of the volume of the extracellular fluid, since the reduction in T_{mp}/GFR after sodium chloride infusion was less marked, nor did it seem to be due entirely to alkalinization of the urine since the maximum increase in urinary pH occurred 20-40 min after the maximum decrease in T_{mp}/GFR.

Key words: kidney, lactate, phosphate, tubular absorption.

Abbreviations: GFR, glomerular filtration rate; T_{mp}/GFR, maximum rate of renal tubular reabsorption of phosphate/unit of GFR.

Introduction

Bronn & Harrison (1971) have shown that an intravenous infusion of hypertonic sodium DL-lactate produces a decrease in plasma inorganic phosphate concentration in man. However, since hypertonic sodium lactate was compared with isotonic sodium chloride, their experiment did not exclude the possibility that this effect might be due simply to expansion of the volume of the extracellular fluid (Stele, 1970), nor were measurements made of urinary phosphate excretion. The work described in the present paper was designed to determine the contributions of extracellular volume expansion and urinary losses to this effect of sodium lactate.

Subjects and methods

Five volunteer members of staff (four men, one woman; age range 21–31 years) were studied. Each subject gave informed consent and the study was approved by the Medical Ethics Committee. One subject had idiopathic hypercalciuria but otherwise they were all considered healthy. Each subject served as his or her own control and was studied at the same time of day on 2 separate days (with 1 week’s interval). They were studied after fasting overnight and were asked to drink about a litre of tap water between waking and the beginning of the study. At about 08.30 hours, an indwelling intravenous cannula was inserted into each forearm. One was used for intermittent blood sampling and the other was connected by plastic tubing to a syringe mounted in an infusion pump (Sage Instruments, model 355). From 09.00 to 09.40 hours, sodium chloride solution (154 mmol/l) was infused at a rate of 1 ml/min while basal samples of blood and urine were collected, both on control and test days. Between 09.40 and 10.00 hours, a total of 2.5 ml/kg body weight of one of the following solutions was infused at a
constant rate: on the control day, sodium chloride (865 mmol/l), and on the test day, sodium DL-lactate (865 mmol/l, containing 55% and 45% of the L- and D-isomers respectively). Blood and urine samples were collected for 2 h after the infusion. Urine samples were collected by voluntary voiding at 20 min intervals throughout the study. The pH of each urine was measured immediately (with a pH meter); the volume was then measured and an aliquot set aside for analysis of phosphate and creatinine. After each urine sample was passed, the subject drank about 200 ml of water. Free-flowing blood samples were taken at the mid-point of each 20 min period; 2 ml was immediately deproteinized in 5% perchloric acid at 4°C for determination of glucose and L-lactate, and 8 ml was immediately centrifuged at 4°C and the plasma separated for estimation of inorganic phosphate and creatinine.

Chemical estimations were performed on the afternoon of the study: inorganic phosphate by the method of Gomorri (1942), creatinine by an alkaline-picrate method, glucose by a glucose oxidase method, and L-lactate by using a commercial kit (Boehringer Corporation).

The fractional tubular reabsorption of phosphate during each 20 min period was calculated from the expression

$$T_{\text{mP}}/GFR = 1 - \frac{\text{urine phosphate} \times \text{plasma creatinine}}{\text{urine creatinine} \times \text{plasma phosphate}}$$

$T_{\text{mP}}/GFR$ was derived from corresponding tubular reabsorption of phosphate and plasma phosphate values by using a previously described slide-rule nomogram (Walton & Bijvoet, 1977).

Results are given as mean values ± SEM. The significances of differences between mean values were assessed by Student's t-test for paired data.

Results

Results are illustrated in Fig. 1. The mean blood L-lactate concentration on the test day was 0.87 mmol/l in the basal samples and 1.98 mmol/l at the mid-point of the infusion. It can therefore be assumed that the peak value was approximately 3 mmol/l. After the infusion, blood L-lactate declined, with a half-life of approximately 20 min. There was no change in blood glucose concentration during the study.

Urinary pH decreased slightly on the control day but on the test day increased to reach a peak in the third 20 min period after the infusion. Urinary phosphate excretion increased on both days, but much more markedly so on the test day, the peak increase occurring in the period immediately after the infusion. Mean plasma phosphate decreased on the test day, but at no point was the value significantly different from that on the control day.

Mean tubular reabsorption of phosphate fell slightly on the control day but markedly on the test day (from 0.91 ± 0.01 to 0.80 ± 0.02). GFR (at least as measured by creatinine clearance) showed no consistent change. The increase in

![Fig. 1. Changes in blood L-lactate, urine pH, urinary phosphate excretion, plasma phosphate, tubular reabsorption of phosphate (TRP) and $T_{\text{mP}}/GFR$ after infusions of sodium chloride (○) and sodium DL-lactate (●). Time of infusion is indicated by vertical broken lines. Mean values ± SEM are indicated. *Significant differences (at 5% level) between mean values on the control and test days.](image-url)
urinary phosphate excretion (and fall in tubular reabsorption of phosphate) in the face of a falling plasma phosphate and a steady GFR must therefore be attributed to a fall in net renal tubular reabsorption (an increase in the filterable fraction of plasma phosphate can be discounted). On the test day, the estimated $T_{np}/GFR$ fell from $1.13 \pm 0.01$ mmol/l before the infusion to $0.82 \pm 0.06$ mmol/l in the period immediately after the infusion. Thereafter mean $T_{np}/GFR$ steadily increased again, although it had not recovered to its pre-infusion value at the end of the study period. On the control day, mean $T_{np}/GFR$ fell only slightly, and recovered to pre-infusion values by the end of the study period.

Discussion

Although the decrease in plasma phosphate after sodium lactate was not significantly different from that after sodium chloride in the present study, this is presumably because the amount infused was less than half that used by Bronn & Harrison (1971). The present results indicate that sodium DL-lactate is associated with a decrease in net renal tubular reabsorption of phosphate significantly greater than that produced by sodium chloride. This effect is not therefore due solely to extracellular volume expansion and can be attributed either directly or indirectly to lactate, although it cannot be said whether the effect is due to the L-isomer, to the D-isomer or to both. Since lactate and phosphate are both handled by glomerular filtration and tubular reabsorption, predominantly in the proximal tubule (Pitts, 1974), it seems plausible that they might compete for a transport mechanism. The rapidity of the decrease in $T_{np}/GFR$ after lactate infusion would be consistent with such an idea. Against this idea are results of micropuncture studies in the rat which indicate that lactate reabsorption might be passive and maintained by intracellular utilization for gluconeogenesis (Höhmann, Frohnert, Kinne & Baumann, 1974). If indirect, the effect could be due either to alkalinization of tubular fluid (Mostellan & Tuttle, 1964) or to conversion of lactate into bicarbonate (Puschett & Goldberg, 1969). Alkalinization seems unlikely to be the only reason since the peak increase in urinary pH occurred 20–40 min after the maximal decrease in $T_{np}/GFR$.

References


