

Peritoneal Dialysis Using a Bicarbonate-buffered Dialysate in a Child with an Inborn Error of Metabolism Presenting with Severe Acidosis

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ABSTRACT

Metabolic acidosis is observed in the pediatric intensive care unit (PICU) in several conditions including sepsis, intoxications, and severe catabolic states. It is occasionally seen due to acute decompensation in an inborn error of metabolism (IEM). Persistent acidosis results in a decrease in myocardial contractility, cardiac output, and catecholamine responsiveness. The mainstay of treatment of metabolic acidosis has been intravenous sodium bicarbonate infusion. However, the large amounts of sodium bicarbonate sometimes required can be hazardous resulting in hypernatremia, hypervolemia, and hyperosmolality. We report a 3-year child who presented with persistent lactic acidosis due to an IEM whom we treated with peritoneal dialysis (PD) using a bicarbonate-buffered dialysate. The child recovered uneventfully within 72 hours of dialysis. Peritoneal dialysis using a bicarbonate-buffered dialysate is a safe and simple method of treating persistent severe acidosis in the PICU.

Keywords: Acute peritoneal dialysis, Bicarbonate-buffered dialysate, Inborn error of metabolism, Severe acidosis.

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BACKGROUND

Metabolic acidosis is observed in a large number of conditions in the pediatric intensive care unit (PICU). These include infections, severe catabolic states, tissue anoxia, severe dehydration, and intoxication. It may occasionally be observed during decompensation in an unrecognized inborn error of metabolism (IEM). A decrease in arterial blood pH below 7.1 has been demonstrated to be associated with marked decrease in myocardial contractility, cardiac output, and catecholamine responsiveness. The resultant cardiovascular depression leads to tissue hypoperfusion and lactic acid production.¹⁻³

Control of acidosis is, therefore, essential in the management of these patients. The routine use of sodium bicarbonate in the treatment of most causes of severe acidemia, diabetic ketoacidosis, lactic acidosis, and cardiac arrest has been controversial due to conflicting data on the beneficial and detrimental effects in experimental animals as well as patients.⁴ The large amounts of sodium bicarbonate that are often required could cause serious problems which include sodium overload and cardiac failure, hypernatremia and hyperosmolality, impaired oxygen delivery to the tissues and aggravation of cerebrospinal fluid acidosis, and development of metabolic alkalosis following the correction of lactic acidosis.⁴ Thus, the need for administration of large amounts of sodium bicarbonate, on the one hand, and the potential hazards of this treatment, on the other hand, present a difficult therapeutic dilemma.

We present our experience of using peritoneal dialysis (PD) with a bicarbonate-buffered dialysate for treatment of severe acidosis in a 3-year-old girl who presented with severe lactic acidosis with ketosis.

CASE DESCRIPTION

A 3-year-old Muslim girl from Solapur was admitted with fever, diarrhea, and vomiting for 1 day. Abdominal pain and breathlessness

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were present for 4 hours prior to admission. There was no history of polyuria, polydipsia, loss of consciousness, or convulsions in the past. The child had been hospitalized at 13 months of age with a similar history. Diagnosis at that time had been sepsis with hypoglycemia and metabolic acidosis. She was the third child of a consanguineous marriage (the parents were first cousins). Two older siblings, a 14-year-old boy and a 9-year-old girl were alive and well. There was no family history of a similar problem nor a history of deaths in infancy or early childhood. The child was born normally at term. The neonatal period was uncomplicated. The child was developmentally normal. Immunization was appropriate for age.

On examination, the child was drowsy. Heart rate was 160/minute. Peripheral pulses were feeble. Respiratory rate was 68/minute, acidotic. Blood pressure was 94/60 mm Hg in the right upper limb. The extremities were cool with a capillary refill time of more than 2 seconds. The oral mucosa was dry, but skin turgor was normal. Weight and height were 13.5 kg and 92 cm, respectively, and both above the 50th percentile for age.

There was no icterus nor any other signs of liver cell failure. There were no dysmorphic features. On examination of the abdomen, the

liver was palpable 2 cm below the right costal margin in the mid-clavicular line. There was no splenomegaly. Other systems were essentially normal. There was no peculiar odor to the urine.

Investigations at admission showed hemoglobin of 11.4 mg/dL; total white blood cell count of 18,220/mm³ with a differential count of neutrophils 68%, lymphocytes 29%, and monocytes 3%; and a platelet count of 540,000/mm³. Peripheral smear was negative for malarial parasites. Blood glucose was 315 mg/dL. Serial arterial blood gases and electrolytes are shown in Table 1. Anion gap at admission was 25.4 mEq/L (normal 8–16 mEq/L). Serum creatinine was 0.8 mg/dL which decreased to 0.4 mg/dL at 24 hours. Serum calcium was 9.1 mg/dL and serum uric acid 8.5 mg/dL. Serum ammonia was 57 μmol/L (normal in children: 11–35 μmol/L), and plasma lactate was 14.4 mmol/L. Serum-free fatty acids and 3-OH butyric acid were elevated. Blood culture was sterile. Liver function tests were normal.

A diagnosis of diabetic ketoacidosis was initially made, and the child given fluid boluses. However, blood sugars dropped to 123 mg/dL at 1 hour and were un-recordable at 2 hours; hence, insulin was not started. A diagnosis of an IEM was considered especially with the past history of hypoglycemia and acidosis at 13 months of age. Blood and urine were collected for metabolic workup. Despite three bicarbonate corrections given over a period of 16 hours, there was persistent severe acidosis; hence, a decision was taken to start PD with a bicarbonate-buffered dialysate. Since bicarbonate-buffered dialysate cannot be stored, it was prepared just before use by adding 260 mL of 5% dextrose and 40 mL of 8.4% soda bicarbonate to 700 mL of normal saline (dialysate containing sodium 147 mEq/L and bicarbonate 40 mEq/L).

A rigid PD catheter was inserted percutaneously into the peritoneal cavity through a small midline incision 4 cm below the umbilicus under local anesthesia, using sterile precautions. Peritoneal dialysis was initiated with a fill volume of 30 mL/kg and dwell times of 45 minutes. The child was started on intravenous fluids and an empiric antibiotic—ceftriaxone, pending the blood culture report. Vital signs, mental status, and urine output were monitored prior to, during, and after dialysis as were the arterial blood gases, serum electrolytes, and blood sugars. The child regained consciousness within 6 hours of initiation of dialysis. Metabolic acidosis was under control within 48 hours, and hence, PD was discontinued.

Blood tandem mass spectrometry of blood was normal. Gas chromatography/mass spectrometry of urine showed significantly elevated lactate, 2-OH butyrate, 3-OH butyrate, acetoacetate, and glycerol.

A defect in gluconeogenesis, probably a fructose 1,6 biphosphatase deficiency was considered in view of

hypoglycemia, high anion gap acidosis, hyperlactatemia, ketosis, and presence of glycerol in the urine. Enzyme studies were not available. Genetic studies will be sent as soon as financially feasible. The child was discharged on a fructose-restricted diet with advice to the parents to avoid prolonged fasting. At last follow-up at 10 months, the child is doing well, with no further episodes of decompensation.

DISCUSSION

We report here a case of a child with an IEM who presented with severe metabolic acidosis and was managed with PD with a bicarbonate-buffered dialysate. While PD with bicarbonate added to the PD fluid is a well-known procedure, this is an often forgotten modality of treatment and is useful in small setups where facilities for hemodialysis (HD)/continuous renal replacement therapy (CRRT) are not available.

Our patient presented with hyperglycemia in this admission. Paksu et al.⁵ described a patient with fructose 1,6-biphosphatase who presented with hyperglycemia. They attributed this to stress hyperglycemia associated with sepsis. In our patient, however, the blood culture was sterile. Hyperglycemia was probably due to a dextrose bolus the child had received prior to admission to our PICU. Despite correction of subsequent hypoglycemia and giving three corrections with intravenous sodium bicarbonate over a 16-hour period, our patient continued to have altered sensorium and persistent acidosis. We, therefore, decided to do PD with a bicarbonate-buffered dialysate.

Commercial dialysates available for acute PD contain acetate as the buffer. However, acetate metabolism may be abnormal in patients with severe lactic acidosis. Bicarbonate is a physiologic buffer requiring no metabolic conversion and, hence, is the logical choice for the treatment of metabolic acidosis. With PD, the net sodium and water transfers are negligible due to the lack of significant concentration and osmolar gradients for sodium. However, significant diffusion of bicarbonate and lactate takes place as a result of their marked concentration gradients. Thus, effective removal of lactate and delivery of bicarbonate can be obtained without undesirable changes in the osmolality or the volume of body fluids. Since solute transfer is dependent on the gradient, the rate of bicarbonate delivery during dialysis is self-limited, i.e., the delivery rate decreases with decrease in acidosis and ceases when the metabolic acidosis is corrected. The serum bicarbonate concentration cannot, therefore, rise above that of the dialysate. Undesirable rapid changes of plasma bicarbonate and blood pH, which are commonly encountered with intravenous bicarbonate administration, can be avoided.

Table 1: Serial arterial blood gases and electrolytes of the patient

Hours	0	2	8	12	16	36	48	60	72
pH	7.05	7.23	7.12	7.15	7.13	7.28	7.30	7.33	7.36
pCO ₂ (mm Hg)	8	13	16	14	8	13	14	28	33
pO ₂ (mm Hg)	86	88	92	98	102	108	104	106	102
Serum HCO ₃ (mEq/L)	<3	5.3	6.7	6.2	<3	6.1	11.5	16.7	19.7
Base excess	-26	-20.4	-22.4	-24	-25	-18.8	-19.5	-10	-0.62
Serum Na ⁺ (mEq/L)	133	134.9	137	140	148	143	140	138	137
Serum K ⁺ (mEq/L)	4.2	4.1	3.7	3.1	2.6	3.2	3.5	3.7	4.0
Serum Cl ⁻ (mEq/L)	100.5	101.4	102	104	105	102	101	102	104

Our patient presented with severe lactic acidosis. Peritoneal dialysis with a bicarbonate-buffered dialysate, along with the appropriate supportive measures, resulted in marked improvement of the acid–base parameters. We did not observe hypervolemia or hypernatremia in our patient. Vaziri et al. have also used PD using a bicarbonate-buffered dialysate for the treatment of lactic acidosis in adults, with no adverse effects.⁶

A diagnosis of an IEM in a child may be delayed as the result of nonspecific symptoms. Definitive diagnosis is based on the detection of abnormal levels of amino acids or organic acids, or their metabolites, in urine and/or serum specimens. This may require an additional 24–72 hours, further delaying the initiation of specific medical therapy until the exact metabolic defect is identified. Previous studies have shown that neurologic and developmental morbidities of children with acute metabolic disturbances caused by inborn errors of metabolism increase with prolonged duration of the metabolic derangement.^{7,8} Thus, children with a suspected or confirmed IEM often require therapy to achieve rapid correction of their metabolic disturbance. Exchange transfusions, PD, HD, and CRRT have been used for this purpose; HD and CRRT are preferred since they allow for the efficient removal of toxic metabolites to safer levels, while diagnostic studies are being performed.^{9,10} Most studies have focussed on reduction of hyperammonemia where CRRT is more effective than PD for improving the prognosis.^{9,10}

CONCLUSION

We conclude that PD with a bicarbonate-buffered dialysate is a useful modality for the treatment of persistent severe acidosis in the PICU.

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