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Relationship of metabolic acidosis to urinary sodium excretion in the newborn infant

By

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The relationship between birth weight, postnatal age and acidosis-induced urinary sodium excretion was studied in 43 one-week-old newborn infants with birth weights of 1000—4300 g and gestational age of 28—41 weeks; and in 13 premature infants with birth weights of 1000—1970 g (mean 1620 g) and gestational age of 29—35 weeks (mean, 31.4 weeks) during the first six weeks of life.

Developmental changes were found in acidosis-induced urinary sodium excretion. Newborns with higher birth weight and postnatal age excreted significantly more sodium in response to acidosis than their lighter and younger matches.

It is suggested that the degree of acidosis must be taken into account when estimating the sodium requirement of newborn infants different in birth weight and postnatal age.

Previous studies have revealed a close relationship between sodium homeostasis and acid–base regulation in the neonatal period [11, 20, 22, 24]. In premature infants the limited renal capacity to reabsorb sodium in exchange for hydrogen ion (11, 22] and the low renal threshold for bicarbonate reabsorption [21] due in part to the increased urinary sodium loss [24] are the major factors to be considered in the development of late metabolic acidosis. Evidence is, however, accumulating that not only the urinary sodium excretion influences the acid–base homeostasis, but the degree of metabolic acidosis is also of great importance in controlling fractional sodium reabsorption in the kidney [9, 13, 14, 18, 19, 25].

In an attempt to clarify the role of acidosis in renal sodium handling during the neonatal period, a study was undertaken to investigate the effect of spontaneous or NH_4Cl-induced metabolic acidosis on urinary sodium excretion in newborn infants of various birth weights and of various postnatal ages.

Material and Methods

Two groups of healthy male newborn infants were selected for the study. Group I consisted of 47 one-week-old newborn infants with 1000—4300 g birth weight and of 28—41 weeks gestational age. Group II included 13 premature infants with 1000—1970 g (mean, 1620 g) birth weight and 29—35 weeks (mean, 31.4 weeks) gestational age.

The infants of Group I were studied on the 7th day of life in order to obtain informations as to the influence of birth weight on the relationship between metabolic acidosis and urinary sodium excretion.

The premature infants of Group II were studied on the 7th day of life and then once weekly for 6 consecutive weeks to find out whether postnatal development had any effect on the acidosis-induced changes in renal sodium handling.

The most important clinical characteristics of the newborn infants, the protocol of NH_4Cl administration, the timing of urine collection and blood sampling as well as the acid–base parameters of the blood, and urinary hydrogen ion and calcium excretion have been described in detail [23].

Urinary sodium excretion was determined from urine samples collected during a period of 12 hours, with determination of the acid–base status of the blood before and after NH_4Cl administration.

Sodium measurements were made by flame photometry, acid–base parameters of arterial blood were measured by the method of Astrup et al. [2]. Statistical evaluation was performed by calculating the coefficient of correlation (r) and the equation of exponential regression (y).

Results

Results are shown in Figure 1. It can be seen that metabolic acidosis did not correlate with urinary sodium excretion in infants weighing 1000—1500 g at birth. The increasing acidosis, however, tended to enhance the

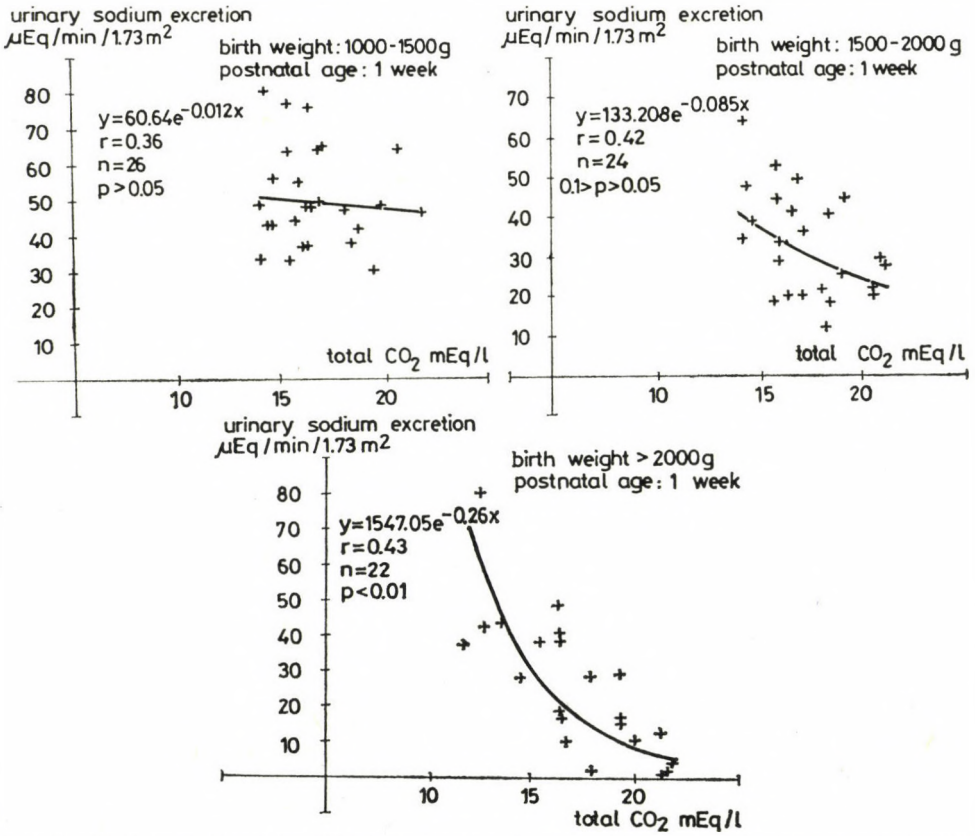

Fig. 1. Birth weight and acidosis-induced urinary sodium excretion in one-week-old newborn infants

urinary sodium loss without statistical significance in premature infants of 1500—2000 g birth weight. When the birth weight was higher than 2000 g, there was a significant inverse correlation between the total blood CO_2 content and renal sodium excretion; i.e. the increasing acidosis resulted in an exponentially increased renal sodium loss.

Figure 2. demonstrates the sequential changes in the acidosis-induced urinary sodium excretion of premature infants during the first six weeks of life. As it is shown, the acidosis did not influence renal sodium handling in the first week (Fig. 2/a). Its effect to raise the urinary sodium loss became more and more pronounced in the second (Fig. 2/b) and in the 3rd to 4th weeks (Fig. 2/c) and, finally, a close negative correlation was found between the total CO_2 of the blood and urinary sodium excretion in the 5th to 6th weeks of life (Fig. 2/d).

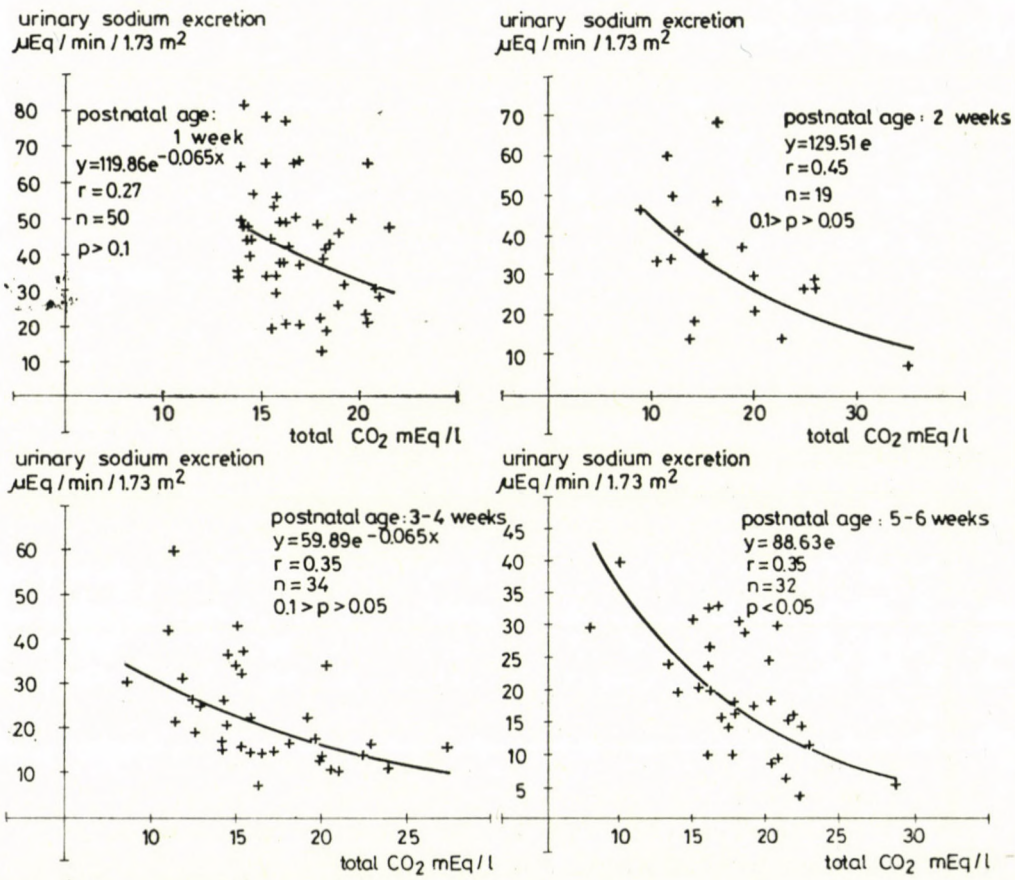

FIG. 2. Postnatal age and acidosis-induced urinary sodium excretion in premature infants

Discussion

The present findings are interpreted to indicate developmental changes in acidosis-induced renal sodium handling taking place either in utero (Fig. 1) or postnatally (Fig. 2).

Several studies have indicated that systemic metabolic acidosis results in a decrease of renal sodium reabsorption in rats [14, 19], dogs [9, 18], and also in humans [13, 25]. In spite of these findings the relationship between metabolic acidosis and renal sodium handling during the neonatal period is not quite clear. There is evidence indicating the existence of such a relationship even in the early period of life.

Late metabolic acidosis of low birth weight premature infants has been shown to cause a failure to gain weight [4, 12, 16, 26] and the increased urinary sodium loss due to acidosis has been considered an important factor in reducing the growth rate [5] Roy et al. recommended sodium supplementation in the form of NaCl or $NaHCO_3$ depending on the base deficit in very low-birth-weight infants for maintaining the normal plasma sodium concentration and for ensuring an adequate growth rate [17].

Our earlier observations that NH_4Cl administration to newborn infants resulted in an increased urinary sodium loss seemed to indicate more directly the modifying effect of acidosis on sodium handling by the neonatal kidney [11, 22]. In the present study we have obtained further information as to the role of metabolic acidosis in renal sodium excretion. It was pointed out that the lower the birth weight and the younger the neonate, the less pronounced the acidosis-induced urinary sodium loss.

We do not suppose that this is a consequence of the decreased responsiveness to acidosis of the immature kidney; it is rather due to factors overriding the effect of acidosis [1]. The main factors to be taken into account are the extracellular volume expansion [3], the high relative total sodium content of the body [15], the tubular unresponsiveness to mineralocorticoids [10], a functional and morphological glomerulotubular imbalance [8] with functional nephron heterogeneity [6, 7], and alterations in the kinetics of enzyme reactions underlying transport mechanism [6, 7].

As gestation advances or the premature infant grows older, the influence of the above-mentioned factors on renal sodium reabsorption is steadily decreasing and the effect of acidosis to enhance urinary sodium excretion becomes more evident.

On the basis of these findings it seems justified to suggest that the severity of acidosis must be taken into account when calculating the sodium requirement of newborn infants of various birth weights and various postnatal ages.

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