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Metabolic changes in newborn infants following surgical operations

II. Acid–base satus of whole blood and erythrocytes, blood lactate and electrolytes

By

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In 29 newborn infants subjected to surgery for congenital anomalies, the extracellular and intracellular acid–base status, and the sodium, potassium and plasma lactate levels were observed from the second to the seventh postoperative days.

During anaesthesia and surgery metabolic acidosis developed but improved spontaneously by the end of the first postoperative day. The metabolic acidosis gradually developing during the postoperative phase was due probably to hypoalimentation.

The plasma lactate level decreased on the first days, then increased slightly; the level showed no statistically significant correlation with the acid–base equilibrium.

In the postoperative period the sodium level decreased gradually in the plasma while in the erythrocytes it was relatively constant. The diminished plasma sodium/potassium ratio was mainly a result of the decreased plasma sodium concentration.

It has been shown that the slight physiological metabolic acidosis of newborn infants is aggravated by anaesthesia and surgical intervention. Furthermore, it was postulated that this intraoperative acidosis may be the result, at least in part, of an intra- and extracellular accumulation of lactate [13]. The electrolyte contents of plasma and erythrocytes during anaesthesia and surgery, as well as in the first 24 postoperative hours, did not change relevantly.

Our observations have now been extended to the 2nd—7th postoperative days to study the intracellular and extracellular acid–base balance, the blood and erythrocyte electrolyte contents, and the concentration of blood lactate in the phase of convalescence.

Materials and Methods

Investigations were performed on 29 newly born babies undergoing emergency surgery for congenital anomalies. The infants were the same as those studied in the first part of this paper (Table I).

Acid–base status of the whole blood (extracellular) was estimated by using the method of Astrup et al. [1]; that of erythrocytes (intracellular) was determined by the method of Gleichmann et al. [8] and Manzke [11] with the following modification: A blood sample of about 0.25 ml was drawn in a heparinized plastic

TABLE I

Electrolyte levels and sodium/potassium ratio of plasma and erythrocytes in newborn infants during the postoperative period.

		Days				
		1	2	3	5	7
Plasma	M	142.5	140.7	139.9	139.2	137.4
Na	n	26	27	24	23	20
mEq/l	±SE	±1.2	±0.9	±1.1	±1.3	±1.3
	p		n. s.	n. s.	n. s.	<0.01
Plasma	M	4.78	4.78	4.20	4.64	5.05
K	n	24	25	24	23	22
mEq/l	±SE	±0.16	±0.17	±0.16	±0.22	±0.20
	p		n. s.	<0.02	n. s.	n. s.
Plasma	M	100	99	105.2	104	100
Cl	n	14	17	14	10	11
mEq/l	±SE	±1.79	±1.93	±1.82	±3.3	±1.67
	p		n. s.	n. s.	n. s.	
Erythrocytes	M	19.6	19.0	19.0	21.1	20.2
Na	n	20	20	17	17	15
mEq/l	±SE	±0.87	±0.77	±0.94	±1.40	±2.30
	p		n. s.	n. s.	n. s.	
Erythrocytes	M	94.7	96.5	93.7	95.1	90.3
K	n	21	22	18	18	16
mEq/l	±SE	±1.43	±1.9	±1.3	±2.55	±2.3
	p		n. s.	n. s.	n. s.	
Plasma	M	30.4	33.6	34.1	32.2	28.0
Na/K	n	23	25	22	21	17
	±SE	±1.17	±1.58	±1.54	±1.87	±0.6
	p		n. s.	n. s.	n. s.	<0.05
Erythrocytes	M	0.204	0.19	0.197	0.22	0.24
Na/K	n	18	18	15	15	13
	±SE	±0.0096	±0.0084	±0.0099	±0.02	±0.033
	p		n. s.	n. s.	n. s.	

M = mean value; n = number of patients; p = significance gained by comparing the postoperative days to the first day after surgery; ± SE = standard error tube 1—1.5 mm in diameter. After centrifugation the erythrocyte mass was frozen with ethyl chloride, then kept in a hot water bath and haemolyzed. In other respects (equilibration, determination), the method was the same as that used by the above-mentioned authors. The word intracellular refers to the measurements in erythrocytes, the word extracellular always refers to measurements performed in whole blood. H^+ means the hydrogen ion concentration. The ratio Hi/He indicates the quotient of the concentration of hydrogen ions in the erythrocytes (Hi^+) and in whole blood (He^+).

Blood lactate and plasma chloride were estimated by the methods described by Barker and Summerson [2] and Clauss et al. [6], respectively. Sodium and potassium concentration was determined by flame photometry. Estimation of sodium and potassium in erythrocytes was carried out from the sediment of red cells obtained after 10 minute centrifugation at 4000 *g*. Erythrocytes were haemolyzed with ion-free water. Sodium and potassium levels in erythrocytes were determined by flame photometry. Postoperative management and diet, collection of blood samples, and evaluation of the results were as detailed in the first part of this paper.

Results

Figure 1 shows the acid–base balance of whole blood and of erythrocytes. The average pH of whole blood obtained at the end of the first postoperative day did not change in the following 24 hours but there was a continuous, statistically significant decrease after the 3rd day. This fall resulted from acid metabolites.

The buffer base decreased from the initial value of 41.5 mEq/l to 38.8 mEq/l and 37.7 mEq/l by the

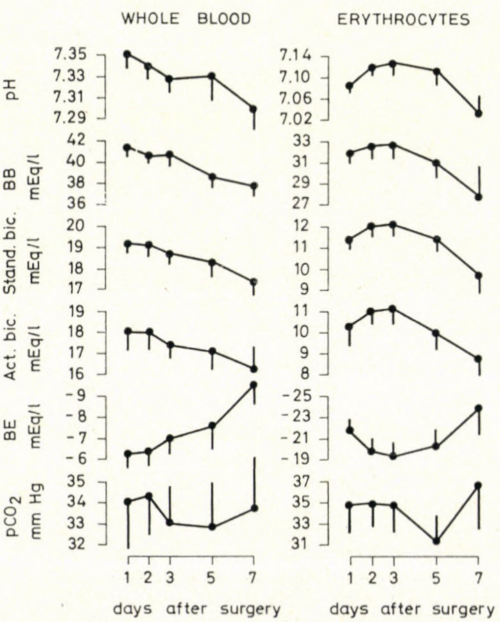

Fig. 1. pH, buffer base, standard bicarbonate, actual bicarbonate, base excess and pCO_2 of whole blood and erythrocytes in newborn infants during the postoperative period. Mean values ± standard error

5th and 7th postoperative days, respectively ($p < 0.05$ and $p < 0.02$).

Standard and actual bicarbonate also diminished. The base excess indicated the accumulation of acid metabolic compounds. The 3.3 mEq/l increase of the base deficit measured at the end of the observation period was significant statistically. In Fig. 1 it is seen that respiratory components had no significant part in the genesis of acidosis. In contrast to whole blood, in erythrocytes the average pH increased by the 2nd, 3rd and 5th postoperative days, but by the 7th day it tended to fall below its initial value. Buffer base was comparatively unchanged during the first 5 postoperative days but by the 7th day a 4.1 mEq/l decrease was noticeable.

Standard and actual bicarbonate behaved similarly as the pH and the base excess, in that a transitory elevation was followed by a decrease. The acid–base status of erythrocytes and whole blood demonstrated a contrasting behaviour of the base deficit in the postoperative period. Base deficit of whole blood was shifted in the acid direction while that of erythrocytes underwent a transitory decrease by the 2nd and 3rd days after surgery ($p < 0.05$), followed by an increase during the next days. The base deficit is of course a reflection of the pH and of standard and actual bicarbonate.

As can be seen in Fig. 2, the 17 mg/100 ml average blood lactate value measured 24 hours after surgery decreased to 13.4 mg/100 ml by the 3rd postoperative day. Subsequently, it reached or just exceeded the initial level.

The relationship between blood lactate and acid–base balance of whole blood and erythrocytes was also followed in the postoperative period. No statistically close correlation between blood lactate and acid–base status was found from the 2nd to the 7th postoperative days, although it could be observed during surgery and in the first 24 postoperative hours. Thus the changes in acid–base balance were not caused by an accumulation of blood lactate as during surgery and on the first postoperative day.

The correlation between the acid–base status of whole blood (extracellular) and that of erythrocytes

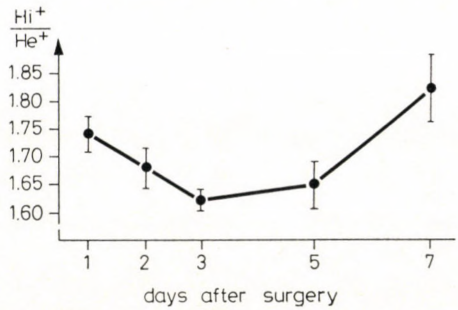

FIG. 2. Blood lactate level in newborn infants during the postoperative period. Mean values ± standard error

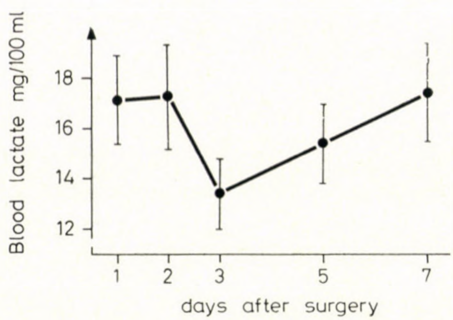

Fig. 3. Quotient of H ion concentration in erythrocytes and whole blood in newborn infants during the postoperative period. Mean values $\pm$ standard error

(intracellular) was examined by calculating the ratio of their H^+ concentration. Thus, the H^+ concentration ratio may be modified either by changes of the numerator (erythrocytes) or of the denominator (whole blood), or by the simultaneous but dissimilar changes of the numerator and the denominator.

Figure 3 shows a decrease in the ratio of H^+ ion concentration on the first 3 postoperative days; the decrease became significant statistically by the 3rd day. However, on the 5th and 7th days after surgery this ratio proved to be higher.

Values for electrolytes measured in plasma and erythrocytes are summarized in Table I. Plasma sodium decreased significantly in the postoperative period ($p < 0.01$) while the plasma potassium, after a transitory decrease, exceeded the initial value ($p < 0.05$). By the 3rd and 5th postoperative days, the moderate elevation observed in the plasma chloride level may have been due to the smaller number of patients examined than in the case of potassium and sodium, and was not significant statistically.

Table I also demonstrates that the sodium concentration in erythrocytes diminished only slightly and then increased on the 5th and 7th days after surgery. On the other hand, the average potassium content of red cells did not reveal a regular pattern. The sodium/potassium quotient of plasma first showed an increase, then decreased significantly by the 7th postoperative day ($p < 0.01$). After a slight fall, the sodium/potassium ratio of erythrocytes rose above its initial value.

Discussion

In the past years, considerable progress has been made in the knowledge of acid–base disturbances in newly born babies. It has been widely recognized that perinatal complications such as metabolic and respiratory acidosis are seriously affecting the adaptation to extrauterine life. Early recognition and due control of these disorders are of great practical importance in modern neonatal care.

In the last two decades, increasing attention has been devoted to the acid–base equilibrium within the cells. In the case of a rapid change of the metabolic and respiratory compounds, a considerable shift occurs between the acid–base balance of whole blood (extracellular) and that of erythrocytes (intracellular). In such cases proper treatment depends on the knowledge of the acid–base status in both compartments.

The results showed that one must take into account a metabolic acidosis not only during surgery and in the first 24 postoperative hours but also later, between the 2nd and 7th postoperative days, when intracellular acidosis may appear. During surgery and on the first postoperative day, a close correlation was found between the accumulation of blood lactate and metabolic acidosis in both erythrocytes and whole blood, while this was absent in the later postoperative period. The metabolic acidosis observed in the postoperative period was presumably due to the combined effect of protein breakdown caused by hypoalimentation, ketonaemia, shifts of electrolytes in the extracellular- and intracellular spaces, and the impaired excretory function of the kidneys.

The relationship between the acid–base status of whole blood and that of erythrocytes is well characterized by the difference of average pH values and the quotient of H^+ concentrations. Battaglia et al. [3] and Manzke [11] found a difference of 0.19 to 0.25 between the pH means in erythrocytes and in whole blood. In our investigations, the differences were 0.26, 0.22, 0.20, 0.22 and 0.27 on the 1st, 2nd, 3rd, 5th and 7th postoperative days, respectively. The difference of 0.26 measured on the first postoperative day can be explained by the slower normalization of acidosis in erythrocytes than in whole blood. On the other hand, the difference of 0.27 of the pHs on the 7th day after surgery was probably due to various degrees of hypoalimentation. The quotient of hydrogen ion concentration in the erythrocytes and in whole blood was reported to amount to 1.51 in adult patients [8], while in newly born infants, to 1.68 [11]. In our material it was also elevated, ranging from 1.71 to 1.82.

In adults, surgical trauma evokes well-characterized changes of sodium, potassium and chloride which are usually proportional to the extent of the intervention [12]. In contrast, newborn infants who underwent surgery do not show such well-defined shifts in plasma concentration of electrolytes [9, 14, 16].

Electrolyte changes in early postnatal life following surgery are different from the patterns seen later in life. To explain them, the characteristics of hormonal and renal regulatory mechanisms of newborn infants must be taken into consideration. Colle et al. [7] showed that in infants subjected to surgery under the age of one week, infusion of ACTH failed to elevate the excretion of 17-

ketosteroid. Rickham [14] called attention to the characteristic pituitary-adrenal relationship in early postnatal age.

In our patients the decrease of pH in erythrocytes and whole blood was associated with a decrease of the potassium level in the red cells. These processes point to the opposite shifts of hydrogen and potassium ions between the intracellular and extracellular spaces after surgery. The side-effects of parenteral feeding should also be taken into account. Chan [5] and Rubecz and Mestyán [15] have shown that intravenous administration of synthetic amino acid mixtures of protein hydrolysates caused acidosis in newborn babies.

Opinions differ concerning the treatment of acid–base disturbances accompanying surgical operations in newborn infants. In the last few years their correction has been considered necessary only in the case of grave disturbances. Borresen and Knutrud [4] advocate that if the acid–base imbalance following a surgical operation is not due to obvious pathological causes, then it could be regarded as a "normal" response within wide limits (standard bicarbonate 15—27 mEq/l, base excess −12 to +4 mEq/l. Tsingoglou et al. [17] too claim that in neonates with intestinal obstruction a disturbance of acid–base equilibrium is uncommon, unless relief of the obstruction is delayed beyond a week. A negative base excess of up to 15 mEq/l is a usual sequence of starvation for 3 or 4 days at any age and does not need to be corrected when oral feeding is begun. In agreement with Young [18] [18], Lewis and Young [10], Borresen and Knutrud [4] and Tsingoglou et al. [17] we believe that the metabolic acidosis appearing after anaesthesia and surgery usually does not need correction. On the other hand, the causes leading to acidosis must be eliminated by avoiding hypoxia and hypovolaemia, and by providing adequate oral or intravenous feeding as soon as possible after surgery.

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