

Disturbances of acid-base equilibrium in infants with congestive heart failure

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In 116 infants with congestive heart failure, the pH, $p\text{CO}_2$ and standard bicarbonate were determined. Half of the patients had acidosis which was mostly of the respiratory type. There was a highly significant difference in pH between the survivors and the patients who died. CO_2 retention differed also significantly in the two groups of infants. An almost linear correlation could be observed between hypercapnia and lethality. Such alterations could not be observed in the standard bicarbonate level. Determination of the acid-base parameters is essential in infants with congestive heart failure, since a reduced pH, besides an increased $p\text{CO}_2$, is indicative of a progression of the disease.

Acid-base equilibrium, as one of the numerous regulatory mechanisms of circulation, is particularly important to the understanding of the fundamental physiologic characteristics of infants [3, 5, 7, 12, 19, 20]. In the present study, the acid-base parameters were determined and evaluated in infants with congestive heart failure.

MATERIAL and METHOD

A total of 116 infants more than 8 days of age was studied during the four-year period November, 1968, to November, 1972.

The acid-base pattern (pH, $p\text{CO}_2$, standard bicarbonate, base excess) was determined in arterialized capillary blood by ASTRUP's method and the nomograms of SIGGAARD-ANDERSEN [17] and THEWS [23].

In all cases, determinations were carried out on the day of admission and before drug treatment. In further management standard therapeutic principles were employed. In cases with reduced bicarbonate, bicarbonate was introduced in the usual

amount of mEq bicarbonate = base excess \times body weight \times 0.3. Artificial respiration was not applied in any of the cases.

According to the usage common in paediatric cardiology, not only patients under one year of age but all those under 2 years whose body weight did not exceed 10 kg, were regarded as infants.

Development was expressed in percentile values according to the Anthropometric Chart of the Children's Medical Center, Boston. Statistical analysis was carried out by STUDENT's *t* test. Patients who died were presented in special group.

Congestive heart failure was diagnosed on the basis of the following clinical symptoms [1, 6, 18, 19, 20].

1. Tachypnoea
2. Tachycardia
3. Respiratory distress (dyspnoea, cough, chronic or recurrent spastic bronchitis)
4. Cardiomegaly (X-ray signs of pulmonary congestion)
5. Hepatomegaly
6. Oedema (especially on the dorsal surface of hands and feet; unexpected overweight)
7. Rales and/or wheezing

8. Anorexia, vomitus
9. Sweating
10. Disturbed development
11. Paleness
12. Psychomotor restlessness, frightened facies

Of the 116 patients, 114 had a congenital heart defect with pulmonary hyperperfusion as the prevalent haemodynamic alteration. In these patients, the circulatory insufficiency was ascribed to left heart failure [2], while in 12 infants myocarditis, fibroelastosis or rhythmic disorders with a high heart rate resulted in congestive heart failure.

RESULTS

TABLE I

Distribution of pH values in 116 cases of congestive heart failure

pH	n	Per cent
7.30—7.40	52	45
<7.30	57	49
>7.40	7	6

Data presented in Table I show that at admission normal pH values were found in less than 50% of the infants with congestive heart failure. Half of the patients had acidosis, while 6%, alkalosis.

TABLE II

pH	Dead patients		Survivors	
	n	Per cent	n	Per cent
7.30—7.40	3	10	49	57
<7.30	27	90	30	35
>7.40	0	0	7	8

In Table II, the high frequency of acidosis observed in lethal cases is striking. The pH value was normal in more than half of the successfully treated patients, whereas only in

10% of the lethal cases. It was also remarkable that alkalosis occurred in none of the patients who died, only in some of the survivors.

Values for standard bicarbonate and $p\text{CO}_2$ are seen in Fig. 1.

Evaluation of the changes of the three parameters shown in Fig. 1 allowed the following conclusions.

Mean pH in the dead patients indicated severe acidosis, while in the survivors the pH was normal. The difference between the two groups was highly significant, $p < 0.001$.

The $p\text{CO}_2$ was elevated in both groups, and especially in the patients who later died. The difference between the two groups was highly significant, $p < 0.001$.

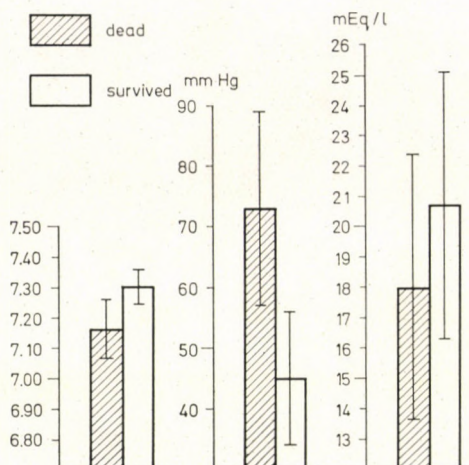
Standard bicarbonate was reduced in both groups but the change was smaller than that of the $p\text{CO}_2$. The difference between the two groups was significant, $p < 0.01$.

The above results indicate that the increased $p\text{CO}_2$ was the factor responsible for the severe acidosis in the patients who died.

TABLE III

$p\text{CO}_2$ and lethality of infants with congestive heart failure

$p\text{CO}_2$ mm Hg	Patients investigated n	Patients died	
		n	Per cent
<50	63	1	1.6
>50	53	29	56
<60	88	6	7
>60	28	14	86
<70	101	16	16
>70	15	14	93



pH		pCO ₂		standard bicarbonate				
n	30	86	n	30	86	n	30	86
\bar{x}	7.166	7.305	\bar{x}	73.20	44.38	\bar{x}	17.97	20.73
s	0.095	0.061	s	15.90	11.13	s	4.34	4.41
s _x	0.017	0.006	s _x	2.90	1.20	s _x	0.79	0.47
t ¹¹⁴	9.16		t ¹¹⁴	10.6		t ¹¹⁴	2.95	
p < 0.001			p < 0.001			p < 0.01		

Abbreviations:

n = number of cases
 x̄ = mean
 s = standard deviation

s_x = standard error
 t = Student's test
 p = probability

The results shown in Table III make it evident that, in addition to the acidosis, the increasing CO₂ retention was responsible for death. When different values of pCO₂ were arbitrarily taken as critical thresholds, the subliminal ranges showed a low lethality. This observation, too, pointed to the role of the increased pCO₂ in deteriorating the prognosis.

The primary role of pCO₂ was clearly revealed when the alterations of the standard bicarbonate were analyzed in relation to the pCO₂ values considered critical.

TABLE IV
 Mean standard bicarbonate in relation to different pCO₂ values

pCO ₂ mm Hg	Patients investigated n	Standard bicarbonate mEq/l
<50	63	19.80 ± 5.38
>50	53	19.77 ± 4.24 p < 0.9
<60	88	20.10 ± 5.09
>60	28	18.93 ± 5.01 p < 0.3
<70	101	20.28 ± 4.98
>70	15	16.75 ± 2.82 p < 0.01

The findings shown in Table IV reveal that only extreme increases

of the $p\text{CO}_2$ were accompanied by a significant decrease of the standard bicarbonate value. There was no significant difference between the groups with a critical $p\text{CO}_2$ range of 50 or 60 mm Hg ($p < 0.9$ and $p < 0.3$, respectively).

On the other hand, when 70 mm Hg was regarded as the critical limit, the mean standard bicarbonate values for the two groups showed a significant difference, $p < 0.01$. This, however, agreed well with our conclusion, since it was obvious that an extreme respiratory distress could lead to reduced oxygen supply and in this way affect the metabolic component.

TABLE V

Lethality of congestive heart failure and standard bicarbonate values

Standard bicarbonate mEq/l	Patients investigated n	Dead	
		n	Per cent
< 16	19	6	32
< 18	34	13	38
< 20	57	24	42
< 22	70	26	37

The results shown in Table V also supported the previous statement in that the degree of metabolic disturbance was not closely related to the lethality rate.

DISCUSSION

A pH shift was observed in more than half of the infants with congestive heart failure. Acidosis occur-

red in 90% of the lethal cases and in 35% of the survivors. Mean pH in the two groups was significantly different.

The acidosis was of the respiratory type. The increase in CO_2 was more marked in patients who later died than in those who were treated with success. CO_2 retention was also correlated with the severity of the disease and this could be explained by the pulmonary congestion manifesting itself with a further decrease of the physiologically low pulmonary compliance of the infants [19], causing an increase of the pulmonary right-to-left shunt [5] and of the obstruction of the respiratory tract [1, 6, 7, 10, 11, 12, 13, 15, 21, 22]. An almost linear correlation was observed between lethality and the degree of hypercapnia.

On the other hand, the standard bicarbonate level of infants who later died was not more reduced than that of the survivors and there was no correlation between the value for standard bicarbonate and the rate of lethality.

Significant changes in the standard bicarbonate value were observed only in cases with grave respiratory failure. The metabolic component of the acid-base equilibrium did not prove a sensitive prognostic indicator.

All these findings allow to suggest that in infants with congestive heart failure determination of the acid-base equilibrium has a considerable prognostic importance. Low pH values and/or increased $p\text{CO}_2$ are indicative of aggravation [4, 24].

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