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Fetal pH and postnatal adaptation in preterm vaginal deliveries*

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1 Introduction

The need for adequate perinatal and neonatal care in preterm deliveries has today become widely accepted. By application of continuous fetal heart rate (FHR) monitoring and a more active obstetric management in preterm deliveries a reduced rate of complications has been reported in this vulnerable group of infants [11, 14, 20]. Some studies on FHR monitoring in preterm deliveries have shown that intrapartum asphyxia is associated with an increased incidence of pulmonary complications and mortality [18, 21].

In a previous study we have shown that fetal acidosis can appear frequently among preterm infants during vaginal delivery but not always coexist with ominous FHR patterns [31]. The aim of the present study was to evaluate the postnatal acid-base adjustment to extrauterine life during the first 30 minutes of life in preterm infants in relation to fetal pH and maturity at birth. Would information about fetal pH and the minute-by-minute acid-base adaptation of newly born preterm infants enable us to predict their short term outcome and the occurrence of subsequent respiratory problems?

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Curriculum vitae

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2 Material and methods

The material comprises 39 vaginally delivered uncomplicated preterm infants born in the delivery ward in Lund from January 1979 through December 1979. After the initial hour when a standardized program was applied all infants took part in the normal routine care in the Neonatal Intensive Care Unit (NICU) [15, 27].

Besides the study group of preterm infants a control group of 13 term vaginally born infants without risk factors in pregnancy or complications in delivery was followed with similar examinations. Obstetrical data on the preterm infants have been reported earlier [31]. Parental and

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institutional consent have been obtained for the present study.

2.1 Perinatal management

During labor electronic fetal monitoring from 4 cm, pH assessment at 5 cm and full dilation were monitored. The FHR registrations were classified as ominous or innocuous according to criteria in an earlier study [12] Within two minutes after delivery the infant was placed in an Isolette (open incubator) with a servo control radiant heater. The need for resuscitation was determined and the APGAR scoring registered by the neonatologist. Within five minutes continuous monitoring of heart rate, respiration, electrocardiography (ECG) and skin temperature was registered with a HEWLETT-PACKARD 78250 A cardiorespirograph. The environmental temperature was within range of 28 to 30 °C. The state of behaviour (sleep/awakeness) according to PRECHTL [23] was registered as follows: State 1: Eyes closed, regular respiration, no movements. State 2: Eyes closed, irregular respiration, no movements. State 2/4 as above but with interspersed gross movements. State 3: Eyes open, no gross movements. State 4: Eyes open, gross movements. State 5: Crying. The maturity at birth was estimated according to FINNSTRÖM [6].
Blood samples on clamped cord before the first cry and blood samples obtained by capillary heel puncture technique at 5, 30 and 60 minutes and 12 hours of age were analysed for acid-base status, hemoglobine and blood glucose. The blood gases were analysed in an Autocal pH/Blood Gas Analyzer 613 (INSTRUMENTATION LABORATORY).
Extra oxygen (Fi O_2 0.3) was administered during the intitial study period (for 10–30 minutes in 28 and for 1–10 minutes in 9 infants) and at the second study period to all but 5 of the preterm infants.
After the initial 30-minute adaptation period the infant was transported to the adjacent NICU.
At the age of 20 to 28 hours a second 30-minute study period was recorded with cardiorespirograph (CRG) and ECG monitoring.
The ECG recordings have been evaluated after principles applied by ROSÉN et al. [24] with special attention to S – T , P and T changes.
The CRG-findings have been evaluated according to the scoring system proposed by STUDE et al. [26] with total score 4 to 12. Low CRG-scores indicate a higher incidence of abnormalities in the recording. The occurrence of pathological accelerations or decelerations and bradycardia with or without apnoic episodes (> 15 seconds) were registered and graded for the CRG scoring of every infant and the mean CRG score of each study group.
For statistical comparisons Student's t-test or Chi-square test were used when applicable.

3 Results

The 39 preterm infants had a mean birthweight of 2070 ± 557 grams (± 1 SD) and the 13 term infants 3443 ± 424 grams. The boy/girl ratio was 14/25 and 6/7, respectively.
Four infants were preterm and small for gestational age (SGA), i.e. birthweight < – 2 SD, and one preterm and large for gestational age (LGA), i.e. birthweight > + 2 SD. The gestational age distribution among the preterm infants was: 4 (29th–30th week), 8 (31st–32nd week), 9 (33rd–34th week) and 18 infants 35th–36th week). The one-minute APGAR score was < 6 in five infants. Three preterm infants died. Thus the survival rate was 92.3 %.
The range and mean values in preterm and term infants for blood gases in cord blood and at 5, 30 and 60 minutes and 12 hours of age are presented in Tab. I. At 5 minutes of age the mean pH is significantly lower (7.19 ± 0.08) for the preterm infants than for the term controls (7.35 ± 0.06) ($p < 0.01$). In cord blood and 30-minute samples the pH values are the same. The P_{O_2}, P_{CO_2} and BD (base deficit) have almost equal mean values during the time studied. The base deficit shows significant higher values for preterm infants at 30 minutes of age. There is a tendency to persistent elevation of BD still at 12 hours of age. The higher 30-minute P_{O_2} in the preterm infants compared to the controls is probably due to extra oxygen (Fi O_2 0.3) given.
During the initial 30-minute recording the body temperature was between 36.3–37.5 °C in all but two preterm and one control baby (35.0–36.0 °C).

Tab. I. Mean, standard deviation and range of pH, P_{O_2}, P_{CO_2} and base deficit in preterm and term infants in cord blood and at 5, 30, 60 minutes and 12 hours of age.

		Cord blood a	Cord blood v	5 min	30 min	60 min	12 hrs
pH							
preterm	m	7.27± 0.08	7.34± 0.07	*7.19± 0.08	7.25± 0.14	7.26± 0.08	7.35± 0.07
	r	7.12– 7.43	7.14– 7.46	7.00– 7.38	7.06– 7.60	7.11– 7.42	7.15– 7.43
term	m	7.26± 0.10	7.33± 0.09	7.35± 0.06	7.26± 0.05	–	–
	r	7.04– 7.40	7.26– 7.45	7.09– 7.35	7.18– 7.30	–	–
P_{O_2}							
preterm	m	2.8 ± 0.9	3.2 ± 0.8	5.7 ± 1.6	6.1 ± 1.7	6.5 ± 1.7	9.0 ± 5.5
	r	1.5 – 5.2	1.9 – 4.8	3.8 – 9.1	3.6 –10.2	1.1 – 6.2	5.2 –31.3
term	m	2.7 ± 1.2	3.5 ± 1.0	5.6 ± 0.7	4.9 ± 0.5	–	–
	r	1.2 – 5.3	1.8 – 5.2	4.8 – 6.8	4.2 – 5.6	–	–
P_{CO_2}							
preterm	m	4.1 ± 1.6	4.0 ± 1.4	6.4 ± 1.2	5.5 ± 1.2	6.1 ± 1.3	4.7 ± 0.9
	r	1.2 – 7.2	1.5 – 6.7	3.6 – 8.8	2.8 – 8.3	3.3 – 9.8	1.9 – 6.3
term	m	4.5 ± 1.3	4.2 ± 0.9	6.4 ± 0.9	6.8 ± 0.8	–	–
	r	3.1 – 6.9	2.9 – 5.8	4.3 – 7.3	5.9 – 8.2	–	–
Base deficit (mmol/l)							
preterm	m	10.0 ± 5.6	7.5 ± 3.9	8.3 ± 3.9	*8.3 ± 4.8	6.1 ± 4.4	7.6 ±12.3
	r	– 0.5 –20.5	+ 1.0 –18.5	–2.8 –15.2	–0.2 –18.4	+ 1.5 –16.4	+ 4.5 –17.4
term	m	9.2 ± 5.7	5.9 ± 2.9	7.6 ± 4.7	5.7 ± 3.1	–	–
	r	– 3.5 –20.8	–1.5 –10	–2.9 –15.6	–0.5 –10.5	–	–

* p-value < 0.01

In the NICU rectal temperature was below 36 °C in 15 infants at the age of one hour (range 35.2–35.9 °C). At 12 hours of age all had a rectal temperature between 36.0–37.5 °C.

During the two 30-minute CRG-recordings immediately after birth and at 24 hours of age the infant's behavioural states were either state 1 or 2 at the first recording and during the second recording either state 3, 2/4 or 2. Behavioural states did not differ between term and preterm study groups A, B, C, I and II (vide infra).

3.1 Relation to fetal scalp pH

The study group of preterm infants was divided into two groups according to intrapartal scalp pH values for comparison with the term control infants:

Group A: pH > 7.20 (n = 28) – (= no fetal acidosis)
Group B: pH < 7.20 (n = 11) – (= fetal acidosis)
Group C: pH > 7.25 (n = 13) –
(control group of term infants)

The mean birthweight in Group A was 2287 ± 441 grams, Group B = 1493 ± 444 grams and Group C = 3442 ± 424 grams (± 1 SD). In Group A one and in Group B three infants were SGA.

The mean group blood acid-base values are shown in Fig. 1. The pH values were significantly lower in the preterm infants (Groups A, B) than in the term infants (Group C) at 5 minutes of age. At this age the preterm infants of Group A had a mean pH-value of 7.20 and Group B of 7.14 in comparison to pH 7.35 for the group of term infants ($p < 0.01$). A significantly larger base deficit (B.D.) at 5 and 60 minutes after birth is seen in Group B ($p < 0.01$). At 12 hours of age the B.D. eventually normalizes although intravenous $NaHCO_3$ was given from two hours of age in slow infusion (0.2 ml 0.6 molar $NaHCO_3$ per kg per hour in 10% glucose) in only 5 of 28 Group A and 2 of 11 Group B infants.

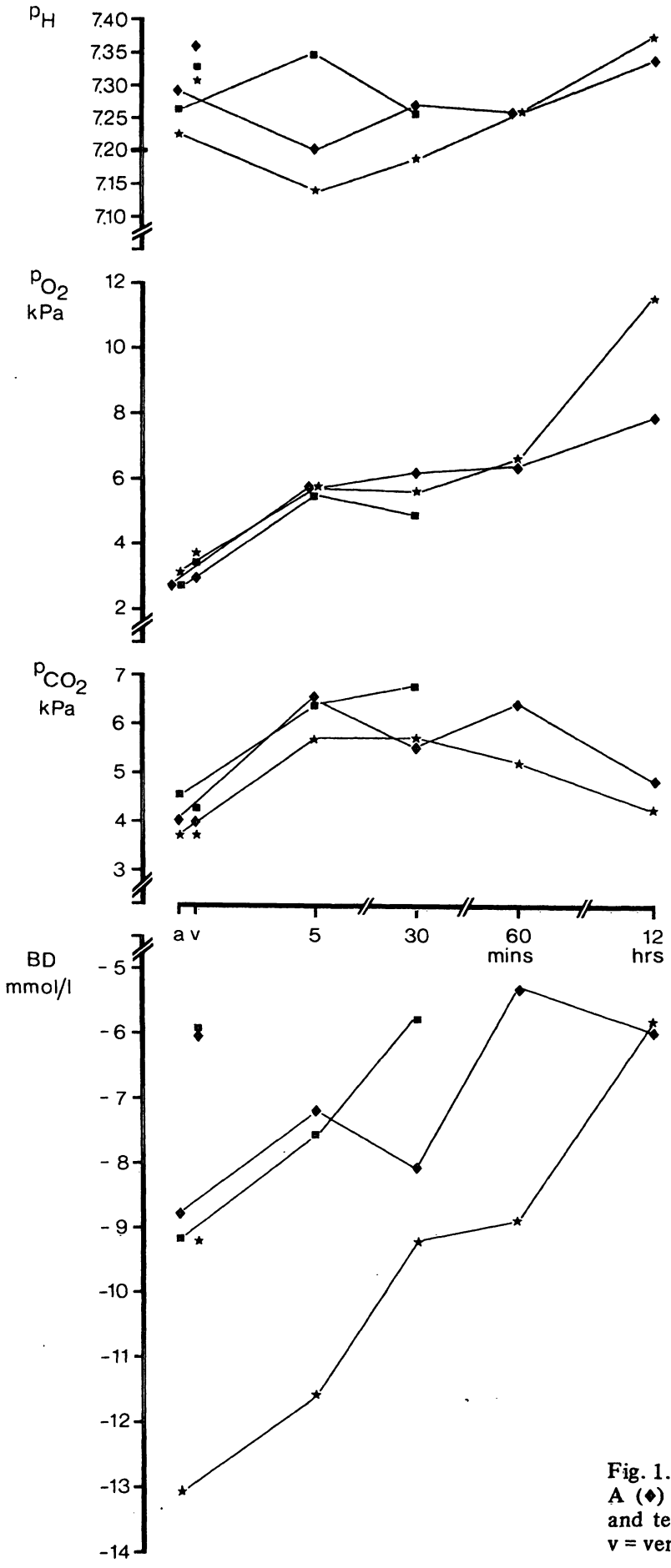

Fig. 1. pH, P_{CO_2}, P_{O_2} and BD in preterm infants Group A (♦) = fetal pH > 7.20, Group B (*) = fetal pH < 7.20 and term infants Group C (■). a = arterial umibilical and v = venous blood.

In Group A the mean hemoglobine value increased about 30 g/l from cord blood (154 ± 25 g/l) to 30 minutes after delivery (179 ± 30 g/l). In contrast the fetal acidosis group (B) only got a 10 g/l hemoglobine increase from 154 ± 28 to 161 ± 20 g/l.

3.2 Relation to gestational age

The preterm infants were also divided into two groups according to gestational age:

Group I 28–33 weeks of gestation (n = 15) and

Group II 34–36 weeks of gestation (n = 24)

The mean birthweight for Group I was 1620 ± 439 grams (± 1 SD) and for Group II 2352 ± 424 grams (± 1 SD).

The acid-base parameters in relation to gestational age are presented in Fig. 2. There is a clear difference in mean pH at 5 minutes after birth between the term infants (pH 7.35) and Group I (pH 7.17) and Group II (pH 7.20) infants. The most preterm infants (Group I) have a lower postnatal mean pH still at 30 minutes of age. In term infants the P_{O_2} and P_{CO_2} stabilize between 5 and 30 minutes of age. The preterm Group I infants have a slightly lower P_{CO_2} during the first 12 hours of life. But no significant differences were found in P_{O_2} and P_{CO_2} between the preterm groups I and II. However, the B.D. of Group I infants are significantly increased over preterm Group II and term infants in the first 60 minutes of life ($p < 0.01$). The postnatal acidosis in Group I thus persists for a longer period indicating a higher degree of metabolic acidosis at birth and a delay in normalization in the smallest preterm infants in Group I.

In the most preterm infants (Group I) 8 of 15 infants (53%) belonged to the fetal acidotic Group B compared to only 3 of 24 Group II infants (12%) ($p < 0.01$).

3.3 Fetal heart rate (FHR) and cardiorespirography (CRG) findings

The intra partum FHR registrations which were made in 38 of 39 preterm infants were classified as innocuous in 21 and ominous in 17 according to obstetrical criteria [31].

The fetal heart rate (FHR) pattern in the fetal pH groups was ominous in 9 (32%) Group A (no fetal acidosis), 8 (72%) Group B (fetal acidosis) but in 0 of 13 Group C (control) infants.

In the two preterm groups according to gestational age 7 of 15 Group I and 10 of 24 Group II infants had ominous FHR monitoring patterns. Neither gestational age, birthweight nor APGAR score revealed any group correlations with intrapartum FHR patterns.

On CRG the heart rate was higher in preterm than in term infants at birth. However, they were all in the same range at 24 hours of age. In preterm Group I infants 66% still had low baseline variability at the 24-hour CRG recording. In contrast this remained in only 20% Group II infants at 24 hours of age. The term infants did not show this type of low baseline heart activity neither at the initial nor at the 24-hour CRG recordings. Within both Group I and II we observed a gradual normalization of pathological accelerations and decelerations as well.

In Tab. II the characteristics for the CRG registrations according to fetal pH groups are presented. The heart rate is higher in the preterm Group A than in Group B and term Group C 0–30 minutes after birth. Low baseline variability and pathologic acceleration and deceleration patterns are slightly more common in Group B infants. The respiratory pattern analysis of the two CRG 30-minute recordings showed only few gross abnormalities. Only few apnoic episodes were registered in the preterm infants (see Tab. II). Evaluation of the respiratory pattern on the CRG recordings did not contribute any further information regarding group differences or later neonatal morbidity.

In Fig. 3 the mean of the lowest CRG score for the different fetal pH groups (A, B and C) are presented. Group B infants have the lowest initial scoring at 0–30 minutes after delivery. At 24 hours Group A and B infants have the same score but still lower than in term infants. The largest difference between the initial postnatal and the 24 hours of age registrations is seen in Group B.

Evaluating ECG-recordings showed no specific pattern like S–T lowering or P-wave dominance over T-wave within any of the study groups A–C, I–II). From the first to the second registration period no distinct changes were seen in any group.

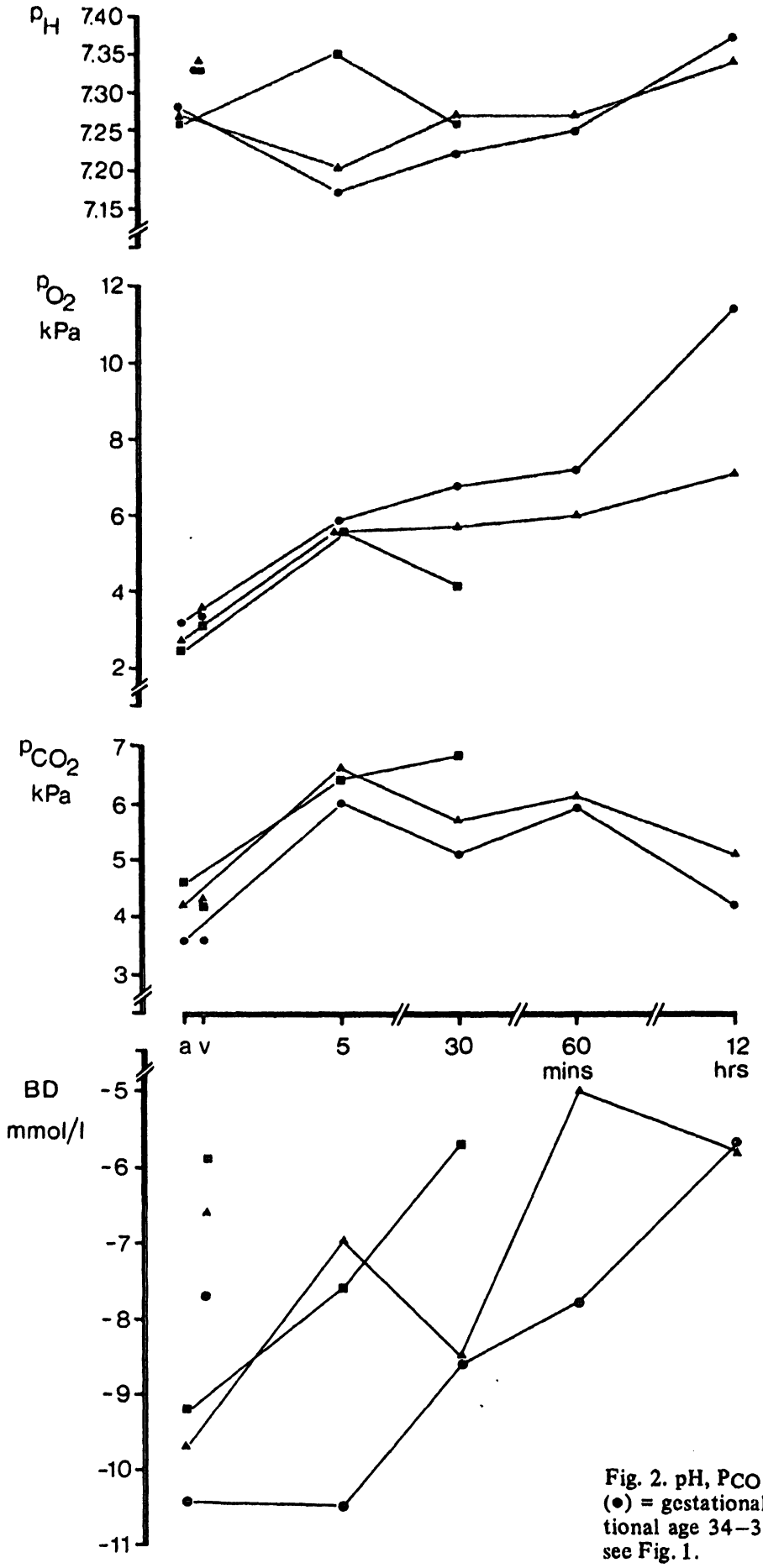

Fig. 2. pH, P_{CO_2}, P_{O_2} and BD in preterm infants Group I (•) = gestational age 28–23 weeks, Group II (▲) = gestational age 34–36 weeks and in term infants (■). a and v, see Fig. 1.

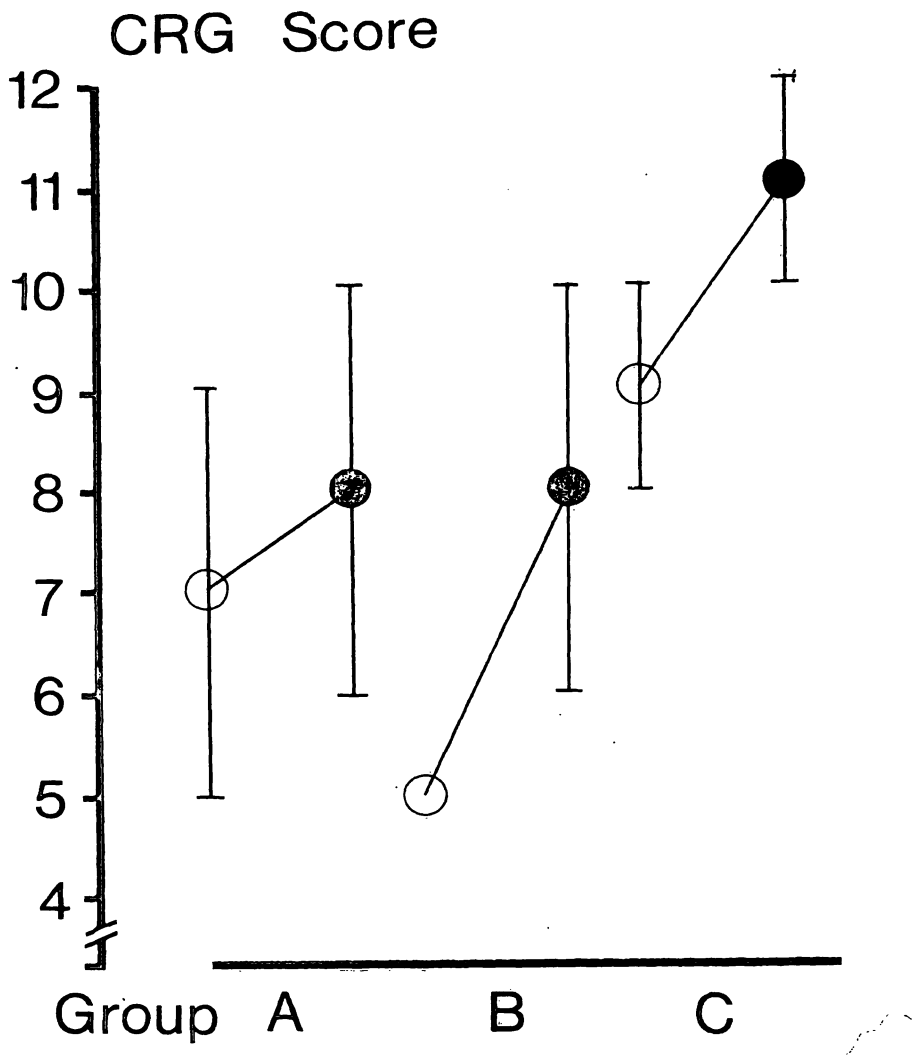

Fig. 3. Mean ± 2 SD minimal CRG score at 0–30 min (○) and 24 hours (●) after birth in preterm groups A, B and term group C.

Tab. II. CRG findings during two 30-minute CRG recordings in relation to fetal scalp pH

Group	Preterm				Term	
	A (pH > 7.20) n = 28		B (pH < 7.20) n = 11		C (pH > 7.25) n = 13	
Age at CRG recording	0–30′	24 hrs	0–30′	24 hrs	0–30′	24 hrs
Heart rate > 150/m	12	3	3	1	3	2
Base line variations < 5	4	1	3	2	0	0
Base line variations > 25	1	1	0	0	1	1
Pathological acceleration	6	2	4	2	1	0
Pathological deceleration	10	2	4	1	2	2
Pathological respiratory pattern	3	1	0	0	0	0
Apnoea > 15 sec	2	2	0	1	0	0

3.4 Postnatal clinical events

In the preterm population no differences were noted in the APGAR scores (Tab. III). All infants cried within one minute after birth. Five infants (2 of 28 Group A and 3 of 11 Group B) required mask and bag ventilation at birth but none was intubated. The mean duration of NICU treatment was 24 days (A) and 59 days (B). After the initial 30 minutes 9 infants needed > 40% oxygen during their NICU stay. Two children in Group B were treated with both CPAP and IPPV. CPAP treatment only was given to 5 Group A and 3 Group B infants. One child in Group A was only treated with IPPV.

Later recurrent apnoeas after 24 hours of age occurred in 7 of 11 Group B versus 5 of 28 Group A infants ($p < 0.01$). The 0–6 months mortality rate was 9% and 7% in Group A and B, respectively.

Tab. III. Clinical data in preterm infants without (A) and with (B) fetal acidosis.

Group		A	B	p-value
Total number		28	11	
Mean APGAR score at	1', 5', 10'	8, 9, 10	7, 8, 10	n.s.
Ventilation support	mask and bag	2	3	n.s.
Mean duration (days) of stay in NICU		24	59	–
Extended O_2 in the NICU	< 40%	18	5	n.s.
	> 40%	5	4	n.s.
Later recurrent apnoea in the NICU after 24 hours of age		5	7	< 0.01
Dead (0–6 months)		2	1	n.s.

4 Discussion

In spite of general improvements in the care of the newborn baby the importance of various postnatal adaptation factors is still not fully known, especially in the very preterm infants. In earlier studies we have evaluated the impact of the mode of delivery in very low birthweight infants [30]. Data on the FHR monitoring and fetal scalp pH have also been reported previously [31].

In the present material we have correlated fetal umbilical pH and postnatal pH and blood gases and CRG. The timing for blood sampling at 5 and 30 minutes after birth was chosen in order to avoid interference from placental oxygenation [17]. Immediately after birth the infants were dried with prewarmed towels and placed in the Isolette open incubator. The importance of skin drying and radiant warmer in order to minimize heat loss was substantiated by DAWES [4]. Poor outcome with cold stress is wellknown in low birthweight infants and related to increased oxygen consumption, hypoglycemia and metabolic acidosis [3]. Besides heat loss insensible water loss also increases with lower gestational age [8]. In our material only 2 preterm infants had temperature below 36 °C in the first 30 minutes and none below 35.2 °C at 60 minutes of life. Thus cold stress was avoided in this study.

In term infants pH declines and base deficit increases transiently but normalizes within 5 to 30 minutes after birth as also shown by others [19, 28, 29].

In the present study the most preterm infants (Group I) did not normalize in pH and BD until 60 minutes or later. In the group of preterm infants with severe fetal acidosis (Group B pH < 7.20) we found the largest B.D. with much slower postnatal normalization than for the other groups. The lower P_{CO_2} in this group is probably a compensatory respiratory response to the prolonged postnatal acidosis following intrapartal acidosis in the very preterm infants.

Earlier studies have shown that pH and P_{CO_2} values have a prognostic significance with a high survival rate in infants with pH > 7.20 and low P_{CO_2} values (9,25). In our study there was no difference in mortality rate related to fetal pH.

It has been stated that severity of neonatal illness and long term sequelae would worsen by the trauma of vaginal delivery and the immediate postnatal treatment (1,30). In the present study we found that hemoglobine did not increase postnatally in Group B infants with fetal pH < 7.20 in contrast to the non-acidotic groups. This may be related to pooling the placental blood in the vaginal delivered distressed infant [2]. Our findings thus confirm earlier studies emphasizing the vital importance of stabilisation immediately after birth (7.25), especially in infants before 34 weeks of gestation.

Our data indicate that after 33 weeks of gestation the preterm vaginal delivered infants resemble the term infants in the postnatal pattern of acid-base changes.

The prognostic value of continuous monitoring with FHR and postnatal CRG is difficult to evaluate. It is known that most infants after birth may change rapidly between high and low periods of activity [5]. This may influence heart rate and respiratory pattern. However, in the present study there were no differences between the study groups during CRG. Besides a mixture of frequent and rapid changes in heart frequency and variability as well as in respiratory pattern we found no distinct group characteristics on the initial 30 minutes CRG recording. However, the lowest minimal CRG scores were seen in the fetal acidosis (Group B) preterm infants. At the second CRG recording period at 24 hours of age the respiratory pattern also remained more irregular in the most preterm infants although the minimal CRG score had improved (Fig. 3). This might be an expression of postnatal pulmonary adaptation mechanisms in order to clear the airways from fetal water and prevent atelectases, by subclinical grunting as described previously in such infants (13, 16). The most preterm infants with low fetal pH (Group B) also had low beat-to-beat heart rate variability on CRG. In our earlier study we found similar patterns on FHR (fetal heart rate) monitoring in fetuses before 34 weeks of gestation [31]. This has also been observed in sick hypoxic newborn infants and is an indication of the vulnerability of very low birthweight infants in this period of life [10, 22].

In conclusion we have found a high rate of low fetal intrapartal pH in preterm infants born before 34 weeks of gestation. The impact of this acidosis may be alleviated by optimum postnatal conditions considering in detail minute-by-minute postnatal adaptation. It indicates that today the risk of premature birth per se is mainly related to deliveries before the 34th week of gestation. Thus 34 rather than 37 gestational weeks should be considered the limit or boundary of prematurity with regard to capacity of immediate postnatal adaptation.

Summary

The postpartum adaptation to extrauterine life was studied in 39 preterm (< 37 weeks of gestation) and 13 term vaginally born infants. Fetal scalp pH during delivery was measured in every baby. Acid-base balance was followed with repeated measurements during the first 30 minutes and at 1 and 12 hours post partum. Heart rate and respiration was monitored with a cardiorespirograph (CRG) during the first 30 minutes and at 24 hours of age. The results showed a **more extended delay in acid-base regularisation in the group of preterm infants less than 34 weeks of gestation with low fetal scalp pH (< 7.20).** There was no group difference in postnatal acid-base balance and cardiorespiratory adaptation for infants born after 33 weeks of gestation in camparison to term infants.

It is suggested that as regards the capacity for postnatal adaptation 34 rather than 37 gestational weeks should be considered the limit of prematurity.

Keywords: Cardiorespirography, fetal pH, postnatal acid-base balance, preterm infant.

Zusammenfassung

Fetaler pH und postnatale Adaptation bei vaginal geborenen Frühgeborenen

Wir untersuchten die Adaptation an das extrauterine Leben von auf vaginalem Weg 39 zu früh (< 37. Schwangerschaftswoche) und 13 am Termin geborenen Kindern. Bei allen Kindern wurde während der Entbindung der pH des Skalpblutes bestimmt. Der Säure-Basen-Status wurde durch wiederholte Messungen während der ersten 30

Minuten sowie eine bzw. zwei Stunden nach der Geburt erfaßt. Mit einem Kardiorespirographen (CRG) zeichneten wir Herzfrequenz und Atmung während der ersten 30 Minuten sowie nach 24 Stunden auf. Unsere Ergebnisse zeigen eine **verzögerte Regulierung des Säure-Basen-Status in der Gruppe der Frühgeborenen mit einem niedrigen pH in der Kopfhaut (< 7.20), die vor der 34. Woche geboren wurden.**
Neugeborene, die nach der 33. Schwangerschaftswoche geboren wurden, zeigten hinsichtlich des postnatalen Säure-Basen-Status und der kardio-respiratorischen Adaptation keinen Unterschied im Vergleich zu den am Termin geborenen Kindern.
Wir meinen, daß unter dem Gesichtspunkt der postnatalen Adaptation die vor der 34. Schwangerschaftswoche, und nicht wie bisher die vor der 37. Schwangerschaftswoche, geborenen Neugeborenen als Frühgeborene einzustufen sind.

Schlüsselwörter: Fetaler pH, Frühgeborene, Kardiorespirographie, postnatales Säure-Basen-Gleichgewicht.

Résumé

PH foetal et adaptation post-natale dans les accouchements prématures par voie basse
L'adaptation post-partum à la vie extra-utérine a été étudiée chez 39 prématurés (< 37 semaines gestationelles) et chez 13 enfants à terme nés par voie basse. Le pH foetal au scalp en cours d'accouchement a été mesuré pour chaque enfant. L'équilibre acido-basique a été suivi au moyen de déterminations répétées après l'accouchement. La fréquence cardiaque et la respiration ont été surveillées à l'aide d'un cardiorespirographe (CRG) pendant les 30 premières minutes et à 24 heures de vie.
Les résultats mettent en évidence **un délai plus prolongé dans la régularisation de l'équilibre acido-basique dans le groupe des enfants prématurés de moins de 34 semaines gestationelles avec un pH foetal au scalp bas (< 7,20).**
Il n'y a pas de différence dans l'équilibre acido-basique post-natal et dans l'adaptation cardio-respiratoire chez les enfants nés aprèa 33 semaines de gestation comparés aux enfants nés à terme.
Les auteurs suggèrent qu'eu égards à la capacité d'adaptation postnatale, la limite pour la prématurité devrait se situer à 34 semaines plutôt qu'à 37 semaines.

Mots-clés: Cardiorespirographe, équilibre acido-basique post-natal, pH foetal, prématuré.

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