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Transcutaneous carbon dioxide measurements in the fetus during labor

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1 Introduction

The interest of measuring the fetal acid-base balance as an aid to the interpretation of abnormal fetal heart rate patterns has been amply demonstrated. Yet this measurement has not been brought into routine practice. Among the reasons underlying this reluctance is the invasive nature of the method and lack of knowledge on the part of most obstetricians concerning the technical problems involved in sampling and also in operating equipment. To solve these problems, an effort has been made with the aim of developing continuous recording methods for fetal pH or blood gases during labor. The use of the pH glass electrode seems still too complicated for routine use and has a high failure rate [4]. Transcutaneous P_{O_2} measurements during labor were demonstrated well correlated to fetal scalp and umbilical artery values [9] however their use to predict fetal asphyxia has been questioned [3]. The interest focused then on the use of a transcutaneous P_{CO_2} for fetal monitoring. This technique was mostly used by two teams in Berlin [6, 7] and Copenhagen [2], which carried out an experimental study and demonstrated its reliability. The results obtained were so stimulating that an evaluation of the practicability of this electrode in an enlarged scale by teams less well aware of technical problems could be envisaged. Our work presents a first evaluation in routine practice.

2 Material and methods

After informed consent, 40 women entered the study. During labor fetal heart rates were monitored by scalp electrodes and contractions by intrauterine catheter in all 40 women.

The E 5230 transcutaneous carbon dioxide electrode was used with the TCM 20 monitor (Radiometer). A two-point calibration of the electrode was performed with 5% and 10% carbon dioxide. The electrode temperature used for both calibration and measurements was 41 °C.

The electrode was applied through an amnioscope and fastened to the scalp by an attaching ring glued with Histoacryl® (Bruneau, France). The fetal head was not shaved before application.

Of the 40 tracings obtained only 36 could be interpreted. The characteristics of the patients corresponding to these tracings were as follows: primiparae: 23 cases, multiparae: 13 cases, normal pregnancies: 34 cases, Rhesus immunization: 1 case, intrauterine growth retardation: 1 case, epidural analgesia: 32 cases, no analgesia: 4 cases, spontaneous delivery: 31 cases, forceps extraction: 5 cases. All infants had Apgar scores above seven 5 min. after delivery, and only two had an umbilical artery pH under 7.16.

The tcP_{CO_2} electrode was applied at a dilatation of 4 cm in 13 cases, 5 cm in 11 cases, 6 cm in 8 cases, and 8 cm in 4 cases.

After delivery, umbilical and venous blood samples were analyzed; pH being determined in 32 cases, P_{CO_2} in 19 cases.

3 Results

In 30 cases the tracing was obtained after a single application of the electrode, while the electrode was applied twice in 3 cases, three times in 1 case and four times in 2 cases.

The mean duration of the recordings was 116 minutes (range: 15–300 minutes). The mean time required to obtain the steady-state was 27 minutes (range: 10–45 minutes). The mean percentage of interpretable tracings was 90% (range: 50–100%).

Table I reports mean tcPco₂ values, uterine contraction parameters, and basal fetal heart rate in relation to the dilatation.

Table I. Mean values of tcPco₂, uterine parameters, and fetal heart rate according to the stage of labor.

Dilatation stage	4–6 cm		6–10 cm		2nd stage	
	m	SD	m	SD	m	SD
Basal tone (mmHg)	8	3	11	4	13	7
Intensity (mmHg)	49	13	51	9	80	19
Interval between contractions (second)	146	18	150	37	128	25
Uterine activity (Montevideo unit)	202	59	214	62	380	127
FHR (beats/min.)	139	18	138	10	135	12
tcPco ₂ (mmHg)	48	6	47	8	47	15

The study of correlations showed a significant correlation between tcPco₂ and the interval between contractions in the 6–10 cm dilatation period (figure 1).

No infant showed an abnormal fetal heart rate baseline during labor. Two infants had a high percentage of late decelerations (40% and 60%), increased tcPco₂ (58 and 52 mmHg), an umbilical artery pH of 7.18 and 7.28 and Apgar scores of 7 and 10 (1 minute after delivery) and 10 and 10 (5 minutes after delivery).

Table II reports the mean values of pH and Pco₂ of the umbilical vessels. Mean of arterial Pco₂ is identical to those of tcPco₂ during labor. However, no significant correlation was found between umbilical artery Pco₂ values and tcPco₂ values during dilatation or the second stage of labor. The coefficient recorded for the 6–10 cm stage was $r = 0.20$ ($n = 19$) and $r = 0.45$ ($n = 9$) for the second stage.

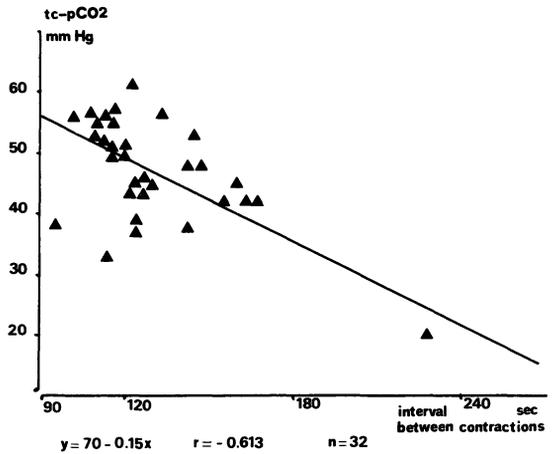


Figure 1. Correlation of tcPco₂ and interval between contractions (measured from peak to peak) during the 6–10 cm stage of dilatation.

Table II. Mean values of pH and Pco₂ of the umbilical vessels.

	Umbilical artery			Umbilical vein		
	N	mean	SD	N	mean	SD
pH	27	7.25	0.06	32	7.36	0.07
Pco ₂ (mmHg)	17	48	14	19	36	8

In only two infants a pH lower than 7.16 was found in the umbilical artery. In case 1 the corresponding tcPco₂ value was 60 mmHg at 9 cm dilatation 15 minutes before delivery. The umbilical artery pH was 7.08, Apgar scores 4/8 at one/five minutes after delivery. In case 2 the tcPco₂ was 50 mmHg at 8 cm dilatation, 30 minutes before delivery. The umbilical artery pH was 7.14, Apgar scores 9/9 at one/five minutes after delivery. Unfortunately, the umbilical artery Pco₂ level was not measured in these two infants.

No resuscitation was required in any of the infants in the series and their clinical condition was normal during the first 6 days following birth.

The range of tcPco₂ values observed was 20–60 mmHg during dilatation and 20–62 mmHg during the second stage. Four infants had a tcPco₂ of 60 or 62 mmHg, umbilical artery pH was unknown for two and 7.24 and 7.29 for the others. Antenatal FHR patterns and Apgar scores at birth were normal in the four cases.

4 Discussion

In this study, the tcPco₂ electrode was used in routine practice. While application presented no major difficulty, some skill was required to solve initial technical problems. Our method of glueing requires the use of an amnioscope, which causes some discomfort to the patient. Tracings were uninterpretable in 10% of cases either for failure of stabilization (two cases) or because values were too low (15 mmHg in two cases). These failures seem to have been caused by faulty fastening. Adherence of the whole circumference of the attaching ring is indeed essential to prevent leakage. But the ring often tends to detach itself, at least partly. In addition, vaginal examinations are liable to detach the electrode. Thus, in our series the electrode had to be applied twice or more often in 20% of the cases and remained correctly fastened during the bearing-down period in only half of the cases.

Most cases studied in this series were normal. Mean values observed are in agreement with those obtained with the same technique by HANSEN et al. [2] in normal cases. As these authors we have obtained values of tcPco₂ on the average identical to those of the umbilical artery. If we compare the results to those obtained by us using fetal scalp blood sampling in similar cases, it seems that tcPco₂ values are higher than scalp values. Indeed, we obtained scalp Pco₂ values of 32 and 37 mmHg in normal labor [5] and epidural analgesia [1], respectively. Furthermore, mean values of Pco₂ in the umbilical artery in these series were 40 and 47 mmHg, respectively. Consequently, mean umbilical artery Pco₂ values during epidural analgesia are higher than mean blood scalp values, but close to the mean tcPco₂ values. These facts demonstrate that tcPco₂ is slightly higher than the scalp capillary blood CO₂ value, which might be explained by CO₂ loss during scalp blood sampling.

In our series, values obtained during the second stage are identical to those of the first stage. On the contrary, THOMSEN and WEBER [8] have observed a significant and linear increase of tcPco₂ during the second stage of labor. This discrepancy is perhaps due to differences in maternal blood gas status, as in their series there was a high degree

of maternal hyperventilation and hypopcapnia, while in our series most women had epidural analgesia, which usually reduces hyperventilation.

We did not find any significant correlation between tcPco₂ and Pco₂ measurements of the umbilical artery. The time elapsed between measurements during the first stage and birth might account for the absence of correlation between umbilical artery Pco₂ and tcPco₂ values of the first stage. However, the correlation between second stage values and umbilical artery values was only slightly improved. This lack of correlation to umbilical artery measurements is in disagreement with the results of others [2, 6, 7, 8]. This discrepancy might be caused by the small number of cases, in which tcPco₂ was measured until just before delivery and correlated to umbilical artery Pco₂ (n = 9). Additionally, the absence of high values in our series (62 mmHg maximum) tends to lower the correlation coefficient. Our only technical problem was that the stabilization time was greater than that of others (average 27 minutes in our series versus 18 minutes [7]). In addition to our lack of training in a new technique, two technical components might explain these differences. Glueing is perhaps less efficient than the suction method used by other groups and the thickness of the hair of infants in Southern France, being appreciably greater than that of German or Danish infants, possibly introduces an additional error factor. To overcome these problems we plan to test fixation by suction and perhaps shaving the measuring area of the fetal scalp before attaching the electrode in instances where the hair is particularly thick.

From a practical point of view, the technique is rather easy to perform. Calibration of the electrode must be done before each use and takes 15 or 20 minutes with the two-point calibration procedure. It seems that using one-point only calibration could reduce this time without impairing the accuracy.

All our cases were normal except one with mild acidosis of the umbilical artery. The tcPco₂ values obtained were in the range of 20 to 62 mmHg. We are now planning to test the technique in pathological cases in order to evaluate its sensitivity in the diagnosis of fetal acidosis.

Summary

Continuous transcutaneous carbon dioxide partial pressure (tcPco₂) was monitored in 40 spontaneous labors. The electrode was attached by glue fixation. An interpretable tracing was obtained in 36 cases. All cases but 2 were normal pregnancies. Thirty-two patients had epidural analgesia while the others had no analgesia. All infants had an Apgar score above 7 at five minutes after delivery and only two had a pH of the umbilical artery of less than 7.16. Mean duration of the recordings was 116 minutes (range: 15–300) and mean time for reaching steady-state was 27 minutes (range: 10–45 minutes). Mean value of tcPco₂ was 48 mmHg (SD: 6) before 6 cm of dilatation, 47 mmHg (SD: 8) between 6 and 10 cm, and 47 mmHg (SD: 15) at the second stage of labor. Mean umbilical artery Pco₂ was 48 mmHg (SD: 14) and mean umbilical artery pH was 7.25 (SD: 0.06). The range of tcPco₂ obtained in these normal cases was 20 to 62 mmHg. Comparison of the results with those of other

authors and with previous studies of normal labor and epidural analgesia show a higher tcPco₂ compared to scalp Pco₂.

In contrast to other studies in these series no correlation was found in the series between umbilical artery Pco₂ and tcPco₂ values. This lack of correlation could be explained either by the small number of cases in which both measurements were available (9 cases) and by the small range of variation or by some inaccuracy in the measurements. However, the good agreement with values obtained by others and with those observed in scalp samples during normal labor is an argument against this last hypothesis. Concerning the technical aspects, the only concern was the long time necessary to reach stabilization, twofold those observed by other authors. This could be due to the fixation technique used (glue versus suction) and to the relative hair thickness of babies in our country.

Keywords: Fetal monitoring, normal range, Pco₂, transcutaneous measurement.

Zusammenfassung

tcPco₂-Messungen am Feten während der Geburt

Der kontinuierliche transkutane Kohlendioxid-Partialdruck (tcPco₂) wurde während 40 Spontangeburt registriert. Die Elektrode wurde mit einer Klebefixierung befestigt. In 36 Fällen waren die Aufzeichnungen auswertbar. Es handelte sich mit Ausnahme von 2 Fällen um normale Schwangerschaften, 32 Patientinnen erhielten eine Periduralanästhesie, die übrigen nicht. Alle Kinder hatten einen 5 Min. Apgar-Wert über 7 und nur 2 hatten in der Nabelschnurarterie einen pH-Wert unter 7.16. Die durchschnittliche Registrierzeit betrug 116 Minuten (Bereich: 15–300) und nach durchschnittlich 27 Min. (10–45 Min.) war der Steady-State erreicht. Bei einer Dilatation unter 6 cm war der Mittelwert des tcPco₂ 48 mmHg (SD: 6), 47 mmHg (SD: 8) bei 6–10 cm Dilatation und 47 mmHg (SD: 15) in der Austreibungsperiode. Der durchschnittliche Wert in der Nabelschnurarterie für Pco₂ war 48 mmHg (SD: 14), der pH-Wert war 7.25 (SD: 0.06). Die tcPco₂-Werte in diesen Normalfällen reichten von 20 bis 62 mmHg. Ein Vergleich dieser

Ergebnisse mit denen anderer Autoren und mit vorausgegangenen Studien bei normaler Geburt und Periduralanästhesie zeigt einen höheren tcPco₂ im Vergleich zum Skalp-Pco₂.

Im Gegensatz zu anderen Studien wurde in den Serien keine Korrelation in den Serien zwischen Nabelschnurarterien Pco₂-Werten und tcPco₂-Werten gefunden. Dieser Mangel an Übereinstimmung könnte entweder durch die geringe Zahl von Fällen, in denen beide Messungen vorlagen (9 Fälle), und durch die geringe Variationsweite oder durch Meßfehler erklärt werden. Die gute Übereinstimmung allerdings mit den Meßwerten anderer und mit denen in Skalpproben unter der Geburt beobachteten Werten spricht gegen diese letztgenannte Hypothese. Hinsichtlich der technischen Aspekte fiel die lange Stabilisationszeit auf. Diese könnte durch die verwendete Fixierungstechnik erklärt werden (Kleben statt Saugen) sowie durch die relative Haardichte der Kinder in unserem Lande.

Schlüsselwörter: Fetale Überwachung, Normbereich, Pco₂, transkutane Messung.

Résumé

Enregistrements de la Pco₂ transcutanée du fœtus au cours de l'accouchement

La Pco₂ transcutanée du fœtus a été enregistrée au cours de 40 accouchements normaux au moyen d'une électrode fixée sur le scalp avec de la colle. Un tracé interprétable a pu être obtenu dans 36 cas. Toutes les grossesses sauf 2 étaient normales. 32 patientes ont accouché sous anesthésie péridurale et 4 sans anesthésie. Tous les en-

fants avaient un score d'Apgar au-dessus de 7 à la 5ème minute. La durée moyenne d'enregistrement a été de 115 minutes (valeurs extrêmes: 15–300 minutes) et le temps moyen de stabilisation de l'électrode a été de 27 minutes (valeurs extrêmes: 10–45 minutes). La valeur moyenne de la tcPco₂ a été de 48 mmHg (écart-type: 6) avant 6 cm de dilatation, de 47 mmHg (écart-type: 8) entre 6 et 10 cm de dilatation et de 47 mmHg (écart-type: 15) au

cours de la phase expulsive, alors que sur l'artère ombilicale la P_{CO_2} moyenne était de 48 mmHg (écart-type: 14) et le pH moyen de 7.25 (écart-type: 0.06). L'intervalle de variation des valeurs observées dans des cas normaux est de 20 à 62 mmHg. La comparaison de ces résultats avec ceux des autres auteurs et avec ceux d'études antérieures sur l'accouchement normal et sur l'accouchement sous analgésie péridurale montre que la tcP_{CO_2} est en moyenne légèrement supérieure à la P_{CO_2} mesurée sur le scalp.

A l'opposé des résultats trouvés par d'autres auteurs, nous n'avons pas observé de corrélation significative avec les valeurs de P_{CO_2} de l'artère ombilicale. Cette absence de corrélation pourrait être expliqué soit par le

faible nombre de cas dans lesquels on disposait des deux mesures (9 cas) et par le faible intervalle de variation (tcP_{CO_2} maxima: 62 mmHg) ou par une certaine inexactitude dans la mesure. Cependant la bonne concordance avec les valeurs obtenues par les autres auteurs et celles obtenues sur le scalp dans les accouchements normaux est un argument contre cette dernière hypothèse. En ce qui concerne les aspects techniques, le seul problème est la relative longueur du temps de stabilisation qui des deux fois supérieur à celui observé par d'autres auteurs. Ceci pourrait être du à la technique de fixation utilisée (colle au lieu d'aspiration) et à la relative épaisseur de la chevelure des nouveaux-nés de notre région.

Mots-clés: Mesure transcutanée, monitoring foetal, P_{CO_2} , valeurs normales.

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