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Suction fixation of the tcPco₂ electrode for fetal monitoring

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1 Introduction

Transcutaneous carbon dioxide monitoring (tcPco₂) in adults and newborn infants is usually performed using fixation rings attached to the skin by adhesive tape. This technique is not possible for monitoring fetal tcPco₂ because the adhesive tape does not attach well on the wet fetal skin. Two different methods for fixation have been used in fetal monitoring, the glue fixation method and the suction fixation method. The ordinary fixation ring used for adult monitoring, modified by removal of the adhesive tape and attached by cyanoacryl glue is used in the glue fixation method. A special fixation ring has been constructed for the suction fixation method. In this paper the suction fixation ring is described, and the influence of the fixation method on fetal tcPco₂ measurements is evaluated.

2 Methods

2.1 The fixation ring for suction application

The suction fixation ring is made of a soft plastic (Elvax 220) measuring 24.5 mm in diameter and 5.8 mm in height (figures 1 and 2). The transcutaneous electrode is pressed into a tight ring (figure 1, a) in the center of the fixation ring and thus attached. A catheter (figure 1, b) made of a harder material (polyethylene) is glued to the ring connecting it to the suction device. The fixation ring is not sterilized by the producer (Radiometer). Gamma ray sterilization is used in our hospital and the suction rings tolerate this treatment well. The plastic material of the ring does not tolerate heating for 60 °C and cannot be sterilized by steam sterilization or formaldehyde steam sterilization.

Figure 1. Cross-section of the suction fixation ring; a. tight ring holding the electrode in position; b. catheter connecting the ring to the vacuum pump; c. skin surface.

Figure 2. The suction fixation ring.

Ethylen oxide sterilization should be possible, but heating during the procedure will spoil the fixation ring. Sterilization by fluid aldehydes immediately

before monitoring is simple, but care must be taken to wash all sterilization fluid away before monitoring to avoid contamination of the fetal skin.

Following cleaning and re-sterilization the fixation ring may be used for more than one monitoring procedure, but the tight ring (figure 1, a) may loosen after a few applications — causing the electrode to slip out of the ring during monitoring. A vacuum of 20 kPa is sufficient to keep the electrode in position on the fetal skin. The vacuum may be produced by an electrical pump or by a central suction system. The calibrated, sterilized electrode is pressed into the fixation ring immediately before monitoring. No cutting or shaving of the fetal hair is performed before monitoring, and no application tools are necessary. At a cervical dilatation of more than 3 cm, following rupture of the membranes, the electrode is applied during a vaginal examination, placing the electrode centrally in the cervical os. Holding the electrode against the fetal skin, the suction is applied, and the electrode is fixed to the skin in a few seconds.

2.2 Preparation of the electrode before monitoring

In order to clean the transcutaneous carbon dioxide electrode (Radiometer E 5230) the electrode membrane must be renewed between each monitoring. A two-point calibration with both 5% and 10% carbon dioxide gas is usually performed. By this procedure the monitor and the electrode are adjusted for electrode drift and the actual sensitivity of the electrode. A less time consuming one-point calibration using only the 5% carbon dioxide gas was used during 30 monitorings. By this procedure a preset "standard electrode sensitivity" is used during the monitoring procedure. To evaluate the accuracy following this one-point calibration the electrode was exposed to the 10% gas immediately after calibration, and the measured carbon dioxide tension was compared to the correct value. Two different electrodes were used for this evaluation, and during the study the age of the electrode increased from a few months to more than one year.

Following calibration the electrode is sterilized by fluid aldehydes (Korsolin® 3%) for 20 minutes. The electrode is carefully rinsed by sterile water to remove all sterilization fluid before application. Drift during the sterilization procedure was evaluated by exposing the electrode to the 5% gas following sterilization in 25 cases.

The tcPco₂ monitor (Radiometer TC 220) needs a slight modification when used for fetal monitoring. The neonatal monitor will interrupt the measurement if the electrode temperature decreases below 30 °C or if maximal electrical effect for electrode heating is used for more than 2 minutes. These electrode conditions will occur during the fluid aldehyde sterilization, and these safety precautions must be cancelled (by the manufacturer) when the monitor is used for fetal monitoring. An electrode temperature of 44 °C was used in our first studies.

2.3 Parameters evaluated during and following monitoring fetal tcPco₂

The actual values of the transcutaneous carbon dioxide tension and the heat consumption are displayed on the monitor. The heat consumption represents the electrical effect necessary to heat the tcPco₂ electrode to the selected electrode temperature (44 °C). The heat consumption changes according to the temperature around the electrode house, and according to the heat absorbed by the skin. Consequently, changes in capillary blood flow, small changes in electrode fixation and temperature changes the surroundings of the electrode influence the values of the heat consumption. The period of time from electrode application until achieving 95% of the stable tcPco₂ value is defined as the stabilization time. Both the time used for heating of the skin to the selected electrode temperature and the in vivo response time are incorporated in the stabilization time, but it is not possible to distinguish which is the contribution of each of these parameters.

The electrode drift during monitoring is measured following each monitoring procedure by exposing the electrode to the 5% carbon dioxide gas.

2.4 Evaluation of the suction method

The suction fixation method was evaluated during adult and fetal measurements by simultaneous monitoring with two electrodes applied by glue and suction fixation.

For the adult monitoring a suction fixation ring and a glue fixation ring were applied on the forearm. The fixation rings were filled with contact liquid and a calibrated tcPco₂ electrode was applied to each fixation ring. Stabilization of the tcPco₂ electrodes was awaited, then the electrodes

were removed, checked for drift, and reapplied in the opposite fixation ring to measure a new stabilization time and Pco₂ value. In this way both electrodes were applied according to the two different methods — glue fixation and suction fixation.

During ten deliveries the methods were compared by simultaneously monitoring fetal tcPco₂ values with two electrodes. The first electrode was applied by glue fixation following amnioscopy and cleaning of the fetal skin. No cutting or shaving of fetal hair was performed as all fetuses were sparsely haired. After removal of the amnioscope, during a vaginal examination the other electrode was applied by suction fixation with placement of the electrode as close as possible to the first electrode.

The tcPco₂ values obtained by the two electrodes were recorded and during the period where both tracings were stable the mean Pco₂ measured by each electrode was calculated. Monitoring at a cervical dilatation of more than 8 cm was evaluated separately.

3 Results

One-point calibration: In 30 monitorings the difference between the measured and the calculated value of Pco₂ never exceeded 0.2 kPa when the

calibrated electrode was exposed to the 10% CO₂ gas. No change of sensitivity was found during the one year period during which the two electrodes were evaluated. An old electrode (more than 2 years old) was rejected by the monitor when the two-point calibration was attempted, whereas a one-point calibration was possible. A considerable difference between the calculated and the measured tension of the 10% CO₂ gas was found in that case.

Drift during sterilization procedure: The mean electrode drift during sterilization by fluid aldehydes was -0.06 kPa and the drift never exceeded 0.2 kPa (figure 3). No drift at all was found in 11 cases. In two cases the sterilization time was prolonged to one hour, but no drift was found in these two cases.

Figure 3. Electrode drift during aldehyde fluid sterilization in relation to the sterilization time.

Figure 4. Tracing of simultaneous monitoring with two tcPco₂ electrodes applied by suction and glue technique on an adult forearm. Starting in the right, electrode no 1 is applied by glue fixation and electrode no 2 by suction fixation. Following a checking for electrode drift, no 1 is applied by suction and no 2 by glue. No difference in stabilization times and tcPco₂ values are found.

Evaluation of the suction fixation method: The adult tcPco₂ monitoring performed simultaneously with electrodes applied with glue and suction fixation is presented in figure 4. Stabilization times and actual tcPco₂ values were identical when measured simultaneously by the two methods.

During ten deliveries fetal tcPco₂ levels were monitored by both suction and glue fixated tcPco₂ electrodes. The median (25–75 percentile) stabilization time by fetal monitoring was by glue application 6.6 min. (3.8–8.4) and by suction application 6.6 min. (5.2–9.2).

The mean tcPco₂ was 9.47 ± 1.58 kPa (mean $\pm$ SD) when measured by glue fixation and 9.11 ± 1.85 kPa (mean $\pm$ SD) when measured by suction fixation. If the values measured at cervical dilatation of more than 8 cm were evaluated, the respective mean values were 9.55 ± 1.8 kPa and 9.55 ± 2.0 kPa ($n = 7$). All values are expressed at 44 °C.

Out of the first 80 monitorings performed by the suction technique, 64 were successful until just before delivery. The tcPco₂ measured just before delivery correlated closely to the Pco₂ of umbilical artery blood. The regression line in figure 5 was calculated following corrections for the electrode temperature of 44 °C [1].

Electrode drift during monitoring was measured in 64 cases (figure 6). The mean drift was -0.14 kPa (2.7%), but in a few cases up to 1 kPa (20%). Monitorings lasting more than 120 min.

Figure 5. Correlation between umbilical artery blood Pco₂ and fetal tcPco₂ measured just before delivery. The tcPco₂ was measured at 44 °C and corrected to 37 °C.

Figure 6. Electrode drift during monitoring in relation to the duration of the monitoring.

had no larger drift than monitorings lasting less than 60 min.

During a series of 45 monitorings in which amnioscopy and cleaning of the skin was not performed the stabilization time was shorter than during the above mentioned series. The median stabilization time in these instances was 2.1 minute with 25–75 percentile of 1.5 to 2.5 minutes.

4 Discussion

The suction fixation method is very easy to perform and the discomfort to the mother is minimal. Previous studies [2] demonstrated identical success rates using the two different methods, but reapplication is more simple to perform when the suction method is used. By glue fixation the electrode membrane is often contaminated by glue at the first application, and before reapplication change of membrane, recalibration, and re-sterilization are necessary. Reapplication must be performed if the electrode falls off or if the electrode is exposed to compression. Electrode compression induces elevation of the tcPco₂ to values much higher than arterial Pco₂ [3]. The small difference in mean values of tcPco₂ found by simultaneous monitoring with electrodes applied by glue and suction fixation, might be caused by compression of the one electrode. In previous studies of neonatal [4] and adult [5] monitoring the coefficient of variation of duplicate measurements was 5% and thus causing more difference than found in this study. At a cervical dilatation of more than 8 cm, when both electrodes usually are free of the cervical edge, no difference between the methods was found.

Stabilization times were the same for the suction and glue fixation methods, but longer than the stabilization times in cases where no amnioscopy

and cleaning of the skin was performed. No contact liquid between the electrode membrane and the skin is used during fetal monitoring, but without cleaning of the skin the natural humidity in the birth channel might serve as contact liquid and thus explain the shorter stabilization time when no cleaning is performed. The one-point calibration method saves time and at normal Pco₂ values the inaccuracy caused by this procedure will be below 0.2 kPa and thus without clinical importance. Nevertheless, the sensitivity of the electrode should be checked with short intervals, because a reduced sensitivity is not detected by the one-point calibration. Long intervals between change of electrode membrane and a high age of the electrode may cause reduced electrode sensitivity. By exposing the calibrated electrode to the 10% carbon dioxide gas the electrode sensitivity is checked in a few minutes. The sterilization procedure with fluid aldehydes does not influence electrode drift, it is easy to perform, and it is sufficient for fetal monitoring.

The close correlation between tcPco₂ and Pco₂ of umbilical artery blood stresses both the value of the transcutaneous technique and the significance

value of the fetal scalp as an area representing acid-base values of the central artery blood. The mean drift of the tcPco₂ electrode is low, but at certain occasions it may be very high. Increasing monitoring time did not affect the drift, just as it was experienced by neonatal monitoring [5]. The drift was found to occur during the application procedure [5] and thus without relation to the duration of the monitoring. The suction fixation method did not influence the drift compared to the glue fixation method.

No complications were seen using the suction fixation method, but in a few cases a red circle was seen on the fetal skin on the day after delivery. This "suction mark" disappeared within a few days and no skin lesion was left. In most of the cases the suction ring had been sterilized by fluid aldehydes, and the "suction mark" may have been a reaction to the fluid aldehydes.

According to our experience the suction technique is an easy application method which allows reapplication and permits a rapid stabilization time. The application technique does not influence the tcPco₂ value during monitoring.

Summary

The fixation ring for suction fixation is made of a soft plastic material and is measuring 24.5 mm in diameter and 5.8 mm in height. The electrode is mounted into the center of the ring and kept in position by the elasticity of the material. A polyethylene catheter is glued into the ring connecting it to the vacuum pump (−20 kPa). The soft plastic material will be deformed by heating, and sterilization should be performed by gamma radiation or by fluid aldehydes. The electrode mounted in the suction ring is attached to the fetal head during vaginal examination without amnioscopy or the use of application tools.

The suction fixation technique was evaluated in relation to the glue fixation technique by simultaneous measurements with two electrodes. In adult monitoring no differences in stabilization times and Pco₂ values were found. In fetal monitoring a little difference (0.3 kPa) in mean values was found at a cervical dilatation of less than 8 cm, but no difference was found at a cervical dilatation of more than 8 cm.

Calibration may be performed by either two-point or one-point calibration. One-point calibration is usually sufficient, but the sensitivity of the electrode should be checked regularly. Electrode sterilization by fluid aldehydes following the calibration does not influence electrode drift.

A close correlation was found between the transcutaneous carbon dioxide tension just before delivery and the Pco₂ of umbilical artery blood ($r = 0.77$, $n = 64$). Stabilization time was short (2.1 min.) and the electrode drift usually low (mean −0.14 kPa or 2.7%) independent of the duration of the monitoring.

The suction fixation method for fetal transcutaneous carbon dioxide monitoring is simple to perform and gives minimal discomfort to the mother. The fixation method does not influence the transcutaneous value of carbon dioxide.

Keywords: Electrode, fetal surveillance, suction fixation, tcPco₂.

Zusammenfassung

Saugfixierung der tcPco₂ Elektrode für die fetale Überwachung

Der Fixierungsring für die Saugfixierung besteht aus weichem Kunststoff und hat einen Durchmesser von 24,5 mm und eine Höhe von 5,8 mm. Die Elektrode wird in der Mitte des Ringes montiert und durch die Elastizität des Materials in dieser Position festgehalten. Ein Polyethylenkatheter wird an dem Ring fixiert und mit einer Vakuumpumpe verbunden (-20 kPa).

Der weiche Kunststoff wird durch Hitze verformt; die Sterilisation sollte durch Gammastrahlen oder Aldehydlösungen vorgenommen werden. Die auf dem Saugring montierte Elektrode wird am fetalen Kopf während einer vaginalen Untersuchung ohne Amnioskopie oder Anwendung von Applikationsinstrumenten angebracht.

Die Saugfixierungstechnik wurde im Vergleich zur Klebefixierungstechnik mittels synchron durchgeführter Messungen mit zwei Elektroden bewertet. Bei der Überwachung von Erwachsenen sind keine Unterschiede in der Einstellzeit und den absoluten Pco₂-Werten gefunden worden. Bei der Überwachung von Feten ist eine geringe

Differenz (0,3 kPa) der Mittelwerte bei einer Zervixdilatation unter 8 cm gefunden worden; es wurde aber keine Differenz bei einer Zervixdilatation von über 8 cm gefunden.

Die Kalibration erfolgte entweder durch eine 2-Punkt oder 1-Punkt Kalibration. Meistens reicht eine 1-Punkt Kalibration aus, jedoch muß die Sensitivität der Elektrode regelmäßig überprüft werden. Die Sterilisation der Elektrode durch Aldehydlösungen nach der Kalibration hat keinen Einfluß auf die Elektrodendrift. Zwischen der transkutanen Kohlendioxidspannung kurz vor der Entbindung und dem Pco₂ im Nabelschnurblut zeigte sich eine enge Korrelation ($r = 0,77$, $n = 64$). Die Einstellzeit war kurz (2,1 Min.) und die Elektrodendrift meistens niedrig (Mittel - 0,14 kPa oder 2,7%) und unabhängig von der Dauer der Überwachung.

Die Saugfixierungsmethode für die fetale transkutane CO₂-Überwachung kann einfach durchgeführt werden und bringt nur minimale Unannehmlichkeiten für die Mutter. Die Fixierungsmethode hat keinen Einfluß auf den transkutanen Wert des Kohlendioxids.

Schlüsselwörter: Elektrode, fetale Überwachung, Saugfixierung, tcPco₂.

Résumé

Fixation par aspiration de l'électrode à tcPco₂ pour le monitoring fœtal

Pour la fixation par aspiration, l'anneau de fixation de l'électrode est en plastique mou et mesure 24,5 mm de diamètre et 5,8 mm de haut. L'électrode est montée au centre de l'anneau et maintenue dans cette position grâce à l'élasticité du matériau. Un cathéter en polyéthylène est collé sur l'anneau et le relie à une pompe à vide (-20 K Pa).

Le plastique mou serait déformé par chauffage, aussi la stérilisation doit être faite par rayons gamma ou par solution d'aldéhydes. L'électrode montée dans l'anneau est placée sur la tête fœtale au cours d'un examen vaginal sans amnioscope ou autre instrument.

La technique de fixation par aspiration a été évaluée par comparaison à la technique de fixation à la colle, au cours de mesures effectuées simultanément avec les deux électrodes. Au cours du monitoring de l'adulte on n'a observé aucune différence dans les temps de stabilisation et les valeurs de tcPco₂. Au cours du monitoring fœtal, une légère différence (0,3 K Pa de valeur

moyenne) a été observée pour une dilatation inférieure à 8 cm, mais aucune différence n'a été observée au delà de 8 cm.

La calibration de l'électrode peut être effectuée soit en deux points soit en un seul. La calibration en un seul point est habituellement suffisante, mais la sensibilité de l'électrode doit être vérifiée régulièrement. La stérilisation par solution d'aldéhydes après calibration n'influence pas la dérive de l'électrode.

Une corrélation étroite a été observée entre la pression transcutanée de dioxyde de carbone mesurée juste avant l'expulsion et la Pco₂ de l'artère ombilicale ($r = 0,77$; $n = 64$). Le temps de stabilisation était court (2,1 mm) et la dérive de l'électrode était habituellement faible (moins de 0,14 K Pa, soit 2,7%) et indépendante de la durée de l'enregistrement.

La fixation par aspiration de l'électrode de mesure de Pco₂ fœtale transcutanée est simple et entraîne une gêne minima pour la mère. La méthode de fixation n'influence pas les valeurs de la Pco₂.

Mots-clés: Electrode, fixation par aspiration, monitoring fœtal, tcPco₂.

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