Relationship between Deceleration Areas in the Second Stage of Labor and Neonatal Acidemia

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Abstract

Understanding the fetal heart rate (FHR) in the second stage of labor is important to recognize critical clinical outcomes. During this time, fetus is subject to head compression that activate baroreceptor reflexes that cause FHR deceleration. Large deceleration areas (DA: measured as duration by depth), have been associated to critical fetal outcomes. A preliminary study on 33 pregnant women reported a significant inverse correlation between DA in the last 60 minutes before delivery and umbilical pH at birth (fetal-distress measure when ≤ 7.1). The aim of this study is to further characterize the relationship between DA in the last 60 minutes before delivery and pH at birth on a larger population. Thus, 433 FHR recordings from the "CTU-CHB Intrapartum Cardiotocography Database" of Physionet were used. Signals were classified as Cases (pH ≤ 7.1) and Controls (pH > 7.1). Results confirmed that Cases have significantly higher DA than Controls (5.32 cm^2 vs 1.44 cm^2; $P < 0.05$). The inverse correlation between DA in the last 60 minutes before delivery and pH at birth, was weak but significant (ρ=-0.23, $P<10^{-6}$). Thus, results confirm that critical fetal outcomes increase with increasing acidemia; however, such relationship may not be strictly linear. Future studies are focused on discrimination of fetal distress using DA.

1. Introduction

Cardiotocography (CTG), also known as electronic fetal heart-rate monitoring, was introduced in 1958 assess fetal well-being during labor [1]. CTG performs auscultation and counting of fetal heart-rate (FHR) during a uterine contraction (UC) [2]. Indeed, as shown in Fig. 1, it consists of two simultaneous recordings (FHR and UC signals) accomplished by means of two separate sensors: a Doppler ultrasound sensor for FHR detection and a pressure transducer for UC detection. Since transducers can be internal or external, CTG is usually performed in noninvasive fashion by using a hand-held probe or external transducer placed on the maternal abdomen by an elastic belt [2].

FHR is controlled by the sympathovagal balance of the fetal nervous system [3]. In the fetal hypoxia condition, sympathovagal balance is altered causing continuous adjustments of FHR in order for it to stay in the normal range (110-160 bpm) [4]. Since fetal hypoxia during labor, especially in the second stage of labor, may cause fetal distress [5], understanding FHR variations in the second stage of labor is of great importance to recognize some critical clinical outcomes [6]. The second stage of labor, which begins when the cervix is full dilated and ends with delivery, has a duration usually ranged between 60 minutes (in nulliparas) and 30 minutes (for multiparas) [7]. During this time, the fetus is often subject to reduced oxygenation [3]. Particularly, UC (which may reach up to 100 mmHg pressure to make fetal head to descend through the pelvis) causes a fetal head compression [6] that causes an increasing of endocranic pressure and a reduction of cerebral flow. Those changes activate baroreceptor reflexes that cause a severe FHR deceleration [5]. If this deceleration is synchronous to UC, it is called "early deceleration"; otherwise, it is called "late deceleration" [8]. While the first is generally considered as a physiological reaction, the second represents a pathologic condition and the fetus may not well tolerate both entity and length of deceleration [2]. Indeed, values of the deceleration area (DA), measured as deceleration duration by depth, have been found to be associated to critical fetal outcomes [9]. In 2013, a preliminary study [10] attempted to quantify this phenomenon previously only qualitatively described. The study, accomplished on 33 pregnant women with FHR

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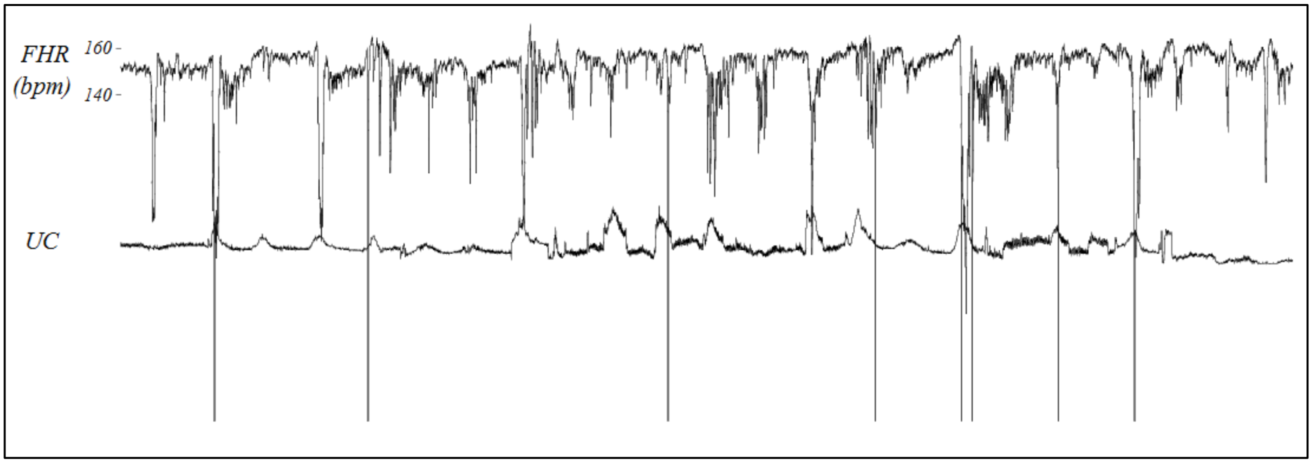

Fig. 1. Example of CTG recording (record 1020) available at "CTU-CHB Intrapartum Cardiotocography Database" of Physionet). Upper panel: the fetal heart-rate time series (FHR, bpm), lower panel: uterine contraction signal (UC).

decelerations in the second stage of labor, reported a significant inverse correlation between DA measured in the last 60 minutes before delivery and umbilical pH at birth, which is considered a measure of fetal distress when ≤ 7.1. Aim of the present work was to further characterize the relationship between DA measured in the last 60 minutes before the delivery and pH at birth on a larger population.

2. Clinical data and methods

Clinical data consisted of 552 CTG recordings containing FHR and a UC signals both sampled at 4 Hz and constituting the "CTU-CHB Intrapartum Cardiotocography Database" [11] of Physionet [12] (http://physionet.org/physiobank/database/ctu-uhb-ctgdb). CTG recordings were acquired by the Czech Technical University in Prague and the University Hospital in Brno. They start no more than 90 minutes before actual delivery and each is at most 90 minutes long. The database is characterized by the following criteria:

- singleton pregnancies;
- gestational age > 36 weeks;
- no a priori knowledge of developmental defects;
- second stage of labor not longer than 30 minutes;
- FHR signal quality (i.e. percentage of the recording during which FHR data were available) > 50% in each 30 minute window;
- availability of biochemical parameters of umbilical arterial blood sample;
- majority of vaginal deliveries (only 46 cesarean deliveries included).
- availability of neonatal pH at birth, obtained from the analysis of the umbilical artery blood sample.

In order to have a homogeneous data set, this study considered only CTG acquisitions for which the last hour of FHR recording (which thus also included delivery) was characterized by at least 90% of valid data (not available data were replaced by mean value). Only these 60-min FHR windows were analyzed in the present study.

As in [10], DA calculated for FHR ≤ 90 bpm was correlated with umbilical pH at birth that was used to classify FHR tracings as Cases, when umbilical neonatal pH ≤ 7.1, and Controls, when umbilical neonatal pH > 7.1.

DA distributions relative to Cases and Controls, were described in terms 50 (median) [25;75] percentiles and compared using the Wilcoxon Rank-Sum Test. Association between DA values and neonatal pH was evaluated by computing of the Pearson's correlation coefficient (ρ) and the area (AUC) under the receiver operating characteristic (ROC). Statistical significance level was set at 0.05 for all tests.

3. Results

Out of the 552 FHR recordings available in the database, 433 (80%) satisfied the inclusion criteria and were thus analyzed in the present study. Of these, 34 were classified as Cases and 399 as Controls. Median DA values for Cases was 5.32 [0;34.29] cm^2 and median DA values for Controls was 1.44 [0;13.62] cm^2. Globally,

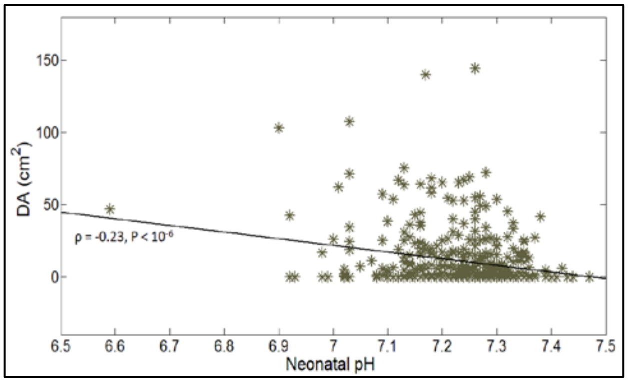

Fig. 2. Deceleration areas (DA) in the last 60 minutes before delivery as function of pH at birth with relative regression line.

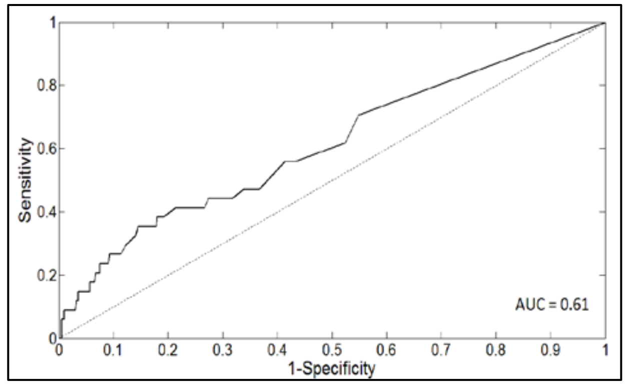

Fig. 3. Receiver operating characteristic (ROC, solid line) with the relative area under curve (AUC) relative to pH at birth.

results confirmed that Cases have significantly higher DA than Controls (5.32 vs 1.44, P< 0.05). A weak although significant inverse correlation (ρ = -0.23, P < 10^{-6}) was observed between DA in the last 60 minutes before delivery and pH at birth (Fig. 2). ROC relative to pH at birth is reported in Fig. 3; AUC was found to be 0.61.

4. Discussion

CTG represents the most commonly used technique for fetal monitoring in clinics, and is a technological application to predict and reduce neonatal critical outcomes [13]. Although CTG is highly reliable for fetal hypoxia identification [14], its predicting value could be enhanced by combining it with fetal electrocardiography (FECG) which records the electrical activity of the fetal heart [15]. Indeed, beside FHR evaluation, FECG allows to have additional information on fetal well-being based on FECG signal morphology, such as ST-segment [16-20]. However, FECG may increase risk of infection when the electrode is directly placed on the fetal scalp [21] or may require significant signal-processing to reduce noise when the electrode in placed on the mother's abdomen [22,23].

Previous studies have suggested a link between fetal hypoxia during labor, especially in the second stage of labor, and fetal distress [5,10]. In turn, fetal hypoxia cause FHR decelerations, each characterized by a duration and a depth. Consequently, DA can be used to characterize a deceleration. Instead, fetal distress can be quantitatively characterized by measuring the pH at birth. Thus, this study followed what done in [10] on a population of 33 pregnant women and attempted a characterization of the relationship between DA measured in the last 60 minutes before delivery and pH at birth on a much larger population. In order to have a homogeneous data set that maintains the same study conditions of [10], 433 60-min FHR windows before delivery were selected from of the 552 available at the "CTU - CHB Intrapartum Cardiotocography Database" of Physionet. To be selected, 60-min FHR windows had to have at least 90% available data. Since FHR could present any spikes (as can be shown in Fig. 1) to 0 bpm related to losses of the contact skin by the sensor, these spikes were corrected in order to enhance the signal quality. In addition, in order to correlate DA and umbilical pH at birth, FHR tracings were classified as Cases (umbilical neonatal pH ≤ 7.1) and Controls (umbilical neonatal pH > 7.1).

According to our results, DA for Cases were always significantly higher than Controls (5.32 cm^2 vs 1.44 cm^2; P< 0.05), thus confirming was observed in [10]. In addition DA was inversely correlated to pH at birth, as observed in [10], but correlation was much lower (ρ = -0.23, P < 10^{-6}) than what previously observed (ρ =-0.77; P<0.05 [10]). The fact that fetal bradycardia (in terms of DA) in the 60 minutes preceding delivery is significantly correlated with the decreasing of neonatal pH, confirms that critical fetal outcomes increase with increasing neonatal acidemia; however, such relationship may not be strictly linear (as the hypothesized by the correlation coefficient). A possible cause of discrepancy between the correlation values found here and in [10] may be due to the presence of several records in which FHR signal has not DA (as it can be seen in Fig. 2). The same not happens in [10], where all FHR recordings in the study population presented severe bradycardia below 90 bpm in the second stage of labor. In addition, the different dimension of study populations (which is equal to 433 for this study and only 33 for the preliminary study) can affect the correlation value.

ROC curve confirms that neonatal pH is characterized by a quite low discriminating power. Indeed, AUC was found to be 0.61 (whereas should be ≥ 0.8 to have a high accuracy value). Given the results found here, DA represents a possible discrimination parameter for identification of fetuses with distress.

5. Conclusion

DA represents a severe fetal bradycardia; associates to critical fetal outcomes and increases with increasing neonatal acidemia. Further investigations are needed to discriminate the fetal distress cases using DA.

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