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Fetal short time variation during labor: a non-invasive alternative to fetal scalp pH measurements?

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Abstract

Objective: To determine whether short time variation (STV) of fetal heart beat correlates with scalp pH measurements during labor.

Patients and methods: From 1279 deliveries, 197 women had at least one fetal scalp pH measurement. Using the CTG-Player®, STVs were calculated from the electronically saved cardiotocography (CTG) traces and related to the fetal scalp pH measurements.

Results: There was no correlation between STV and fetal scalp pH measurements ($r = -0.0592$).

Conclusions: Fetal STV is an important parameter with high sensitivity for antenatal fetal acidosis. This study shows that STV calculations do not correlate with fetal scalp pH measurements during labor, hence are not helpful in identifying fetal acidosis.

Keywords: Fetal acidosis; fetal scalp pH measurements; labor; short time variation (STV).

Introduction

Fetal short time variation (STV) has become an important antenatal parameter to prevent intrauterine acidosis. In 2006, the arterial cord blood pH was 7.10–7.20 in 11.29%, 7.00 and 7.09 in 1.22%, and <7.00 in 0.11% of vaginal deliveries in Germany. An arterial cord blood pH value of <7.0 is considered as critical for cerebral damage [12]. However, 90% of children with such a low pH value have no long-term cerebral damage [28]. In Germany, 74 children born in 2006 would be expected to have a pH value of <7.00 and 10% would be expected to have cerebral lesions. Improving the interpretation of the fetal heart frequency might reduce this number. Subjective cardiotocography (CTG) analysis is limited by a high rate of false positive pathological findings. An additional and objective parameter might improve CTG analysis. STV might be a candidate for better CTG interpretation as Leszcznska-Gorzelak et al. [16] showed a correlation between STV and fetal oxygen saturation. During the 1980s Dawes and Redman developed a computer algorithm, which numerically described the variability of the fetal heart rate. Antenatal studies evaluating >10,000 cardiotocographies demonstrated a correlation of low STV (<3 ms) with fetal acidosis [7, 25]. The computer algorithm divided a minute into 16 equal sectors (each sector covering 3.75 s). In each sector the average heart rhythm was calculated, and the change of each following heart rhythm sector was evaluated. The average of the changes in fetal heart rhythm sectors is the STV. CTGs, which do not fulfill Dawes and Redman criteria (STV<3 ms), were associated with a higher rate of fetal acidosis antenatally and intrauterine deaths [7, 25]. Nowadays computerized CTG analysis is under evaluation and might allow for objective and easy assessment of fetal well-being. However, the analysis of Dawes and Redman is established only for the contraction free period ante partum.

Hove et al. [13] recently analyzed 127 peripartum hypoxic brain injuries from 1992 to 2004; 38 newborns died, and a majority of the 89 surviving children suffered from major handicap, primarily cerebral palsy. In 69 of the cases, misinterpretation of or late action on an abnormal CTG were the reasons for the majority of hypoxic brain injuries and all injuries could potentially have been avoided using established obstetric practice [12]. During labor, however, no computerized algorithms for CTG analysis are available so far and visual analysis of CTG is known for frequent false-positive findings [7, 12, 25, 26]. With the development of new computer software, reliable information about abnormal STV results could be immediately available and might be used for the diagnosis of fetal distress. Therefore, abnormal CTG findings obtained by visual analysis are required to be verified by fetal scalp pH measurements [1, 8, 20]. Fetal scalp pH measurements cannot be performed before cervical dilatation and, in our experience, sometimes might compromise maternal well-being. Exclusion criteria for fetal scalp pH measurements include infections such as hepatitis, HIV, genital herpes simplex or prematurity before

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34 weeks of gestation [11]. Complications described for fetal scalp pH measurements are injury, bleeding and infection [6, 11]. The same contraindications exist for fetal monitoring techniques like ST-analysis using ST segment measurements of the fetal ECG, which is obtained by a fetal scalp electrode.

We hypothesized that computerized STV might be an additional parameter to increase specificity for the evaluation of fetal oxygen supply during delivery and might, therefore, improve the situation with conventional visual CTG analysis alone. High intra- and interobserver variability of CTG readings due to the subjective character of the technique [9, 5, 13, 20] might be reduced by the additional STV parameter. This study examines whether there is a correlation of STV and fetal scalp pH measurements during labor.

Materials and methods

All deliveries, which occurred during 2004–2005 at the Department of Obstetrics and Gynecology, University of Witten/Herdecke (UWH) School of Medicine, were eligible for the study. All 1279 consecutive deliveries were evaluated retrospectively (1) in whom the indication for fetal scalp pH measurement was given, (2) electronically saved CTG tracings, conventional CTG printouts and results of the fetal scalp pH measurements were available in the medical record. All patients' medical records were reviewed, and 197 women met the above criteria. During labor every CTG was centrally monitored and digitally saved (every CTG trace was saved with a resolution of 4 Hz). CTG tracings were evaluated using the CTG-Online® software (Trium®-Analysis Online GmbH, Munich, Germany). In order to correlate fetal scalp parameters with STVs as closely as possible the last 30 min of CTG monitoring before fetal blood sampling were evaluated. The progress of labor and the fetal scalp pH values were documented in the patients' records. The CTG tracing was also printed conventionally.

A total of 320 fetal scalp pH measurements were evaluated from the 197 women. Repeated measurements were performed if a fetal scalp pH was <7.25 in the preceding analysis. If the pH was >7.25, measurements were repeated if pathological fetal heart rate patterns persisted or worsened or in case of a base excess of <9.8 (according to the 2004 recommendations of the German society of gynaecology and obstetrics (DGGG) [8].

First and second stages of delivery were included in this study. Mean gestational age was $39+1$ weeks. From the 197 deliveries 23 were preterm (33–36 weeks' gestation). Patients' characteristics are summarized in Table 1.

Electronically saved CTG traces were evaluated using the offline CTG-Player® program (Trium®-Analysis Online GmbH, Munich, Germany). This software was designed to calculate the STVs using the delayed moving window (DMW). The base excess was also recorded and evaluated. Since pH and base excess are considered as the most reliable predictors of fetal outcome [11] no further fetal blood parameters (pO_2, pCO_2) were used in the present study.

The DGGG divides fetal scalp pH values into three categories (acidosis value ≤ 7.20; pre-acidosis value 7.21–7.24; normal ≥ 7.25) [8]; therefore, pH values were classified into these categories and were then compared with STV data. Statistical analysis was carried out using the SPSS® (Superior Performance Software System, version 15.0.1, Chicago, USA) [24].

Results

Figure 1 shows the STV values and fetal scalp pH measurements. Visual inspection of the graph suggests no clustering of low STV values, a possible indicator of fetal distress, in the area of low scalp pH values (a definite indicator of fetal distress). This is confirmed by not find-

Table 1 Patient characteristics.

Characteristics	Number at UWH
Mother	
Age of the mother (years)	
<20	9 (4.57%)
20–29	88 (44.67%)
30–39	97 (49.24%)
≥ 40	3 (1.53%)
MW $\pm$ SD	29.9 $\pm$ 5.49
Number of previous pregnancies	
0	112 (56.85%)
1	52 (26.39%)
≥ 2	33 (16.75%)
Delivery	
Preterm deliveries	23 (33–36 weeks)
Age of gestation	
MW $\pm$ SD	39 + 1 $\pm$ 10.93
Normal delivery	100 (50.76%)
Forceps extraction	22 (11.17%)
Vacuum extraction	12 (6.09%)
Secondary section	62 (31.47%)
Emergency section	1 (0.51%)
Tocolysis	99 (50.25%)
Number of fetal blood samples for each patient	
1 Sample	111 (56.34%)
2 Samples	59 (29.95%)
3 Samples	20 (10.15%)
4 Samples	4 (2.03%)
5 Samples	3 (1.52%)
Total number of fetal blood samples with the following pH value:	320
pH	
≥ 7.25	273 (85.31%)
<7.25	47 (14.69%)
MW $\pm$ SD	7.30 $\pm$ 0.06
Fetal outcome	
Male	75 (38.07%)
Female	122 (61.93%)
Birth weight (g)	
MW $\pm$ SD	3397.76 $\pm$ 505.66
APGAR 5′	
<7	0 (0.00%)
MW $\pm$ SD	9.76 $\pm$ 0.55
Art. cord blood pH	
<7.25	82 (41.62%)
MW $\pm$ SD	7.25 $\pm$ 0.07

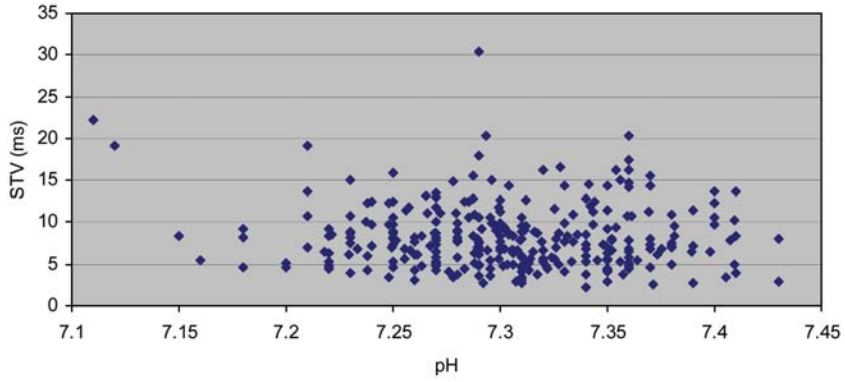

Figure 1 Correlation of STV with fetal scalp pH values.

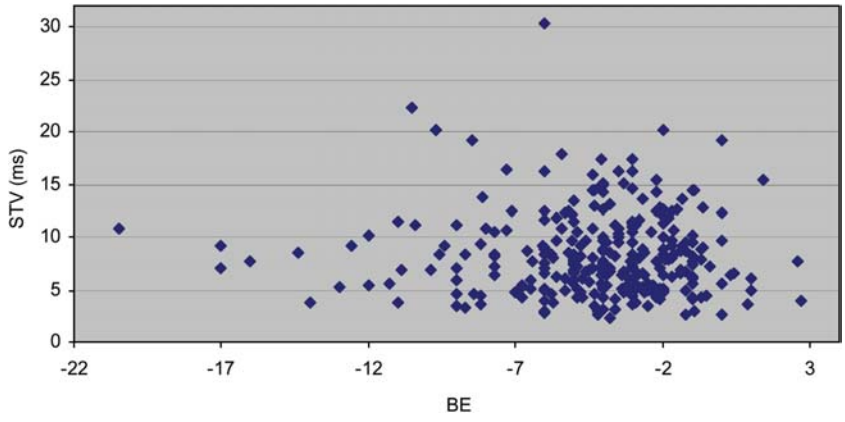

Figure 2 Correlation of STV with fetal base excess values.

ing a statistically significant correlation between STV and fetal scalp pH measurements using the Spearman rank correlation coefficient ($r = -0.0592$). The Pearson-regression was nearly horizontal with a coefficient of –0.0005. There were only seven samples with a pH value < 7.2. However, none of these demonstrated a STV of < 3 ms.

To further evaluate a possible connection between fetal distress and decreased STV we looked at the base excess. Similar to the findings in Figure 1 there was no significant correlation (Spearman rank correlation: $r = -0.0355$; Figure 2). These results suggest no relationship between fetal distress and decreased STV. The Pearson-regression of STV and fetal scalp pH values was also nearly horizontal with a regression coefficient of –0.0291. Although eight fetal scalp blood samples demonstrated a base excess of < 12 mmol/L, none had a STV < 3 ms. None of these newborns had a base excess < 12 mmol/L in arterial cord blood (data not shown).

Figure 3 shows a box-plot for the three categories (acidosis, pre-acidosis and normal fetal scalp pH values) of median, 1st quartile and 3rd quartile values. No significant difference between the STV values for each group was found using the Mann-Whitney test ($P = 0.1887$).

During earlier gestational weeks, fetal heart action is known to be regulated predominantly by the sympathetic system, explaining a smaller range of fetal heart rate variation than in later pregnancy when the influence of the parasympathetic system increases [10]. Therefore, we examined if a relationship exists between gestational age (33–43 weeks) and STV. Figure 4 presents the box-plot-diagram of the STV parameter in correlation of the ges-

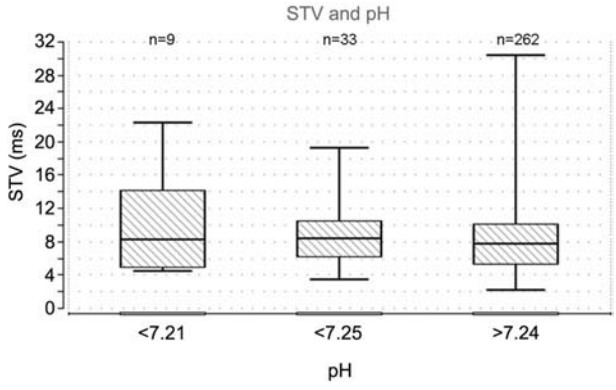

Figure 3 Distribution of STV values of the three categories acidosis, pre-acidosis and normal fetal scalp pH. Box plots show median, 1st quartile and 3rd quartile of values. The three categories did not differ significantly ($P = 0.1887$).

tation age with no significant difference ($P = 0.4378$, Mann-Whitney test.

Discussion

This study shows that STV calculations do not correlate with fetal scalp pH measurements during labor, hence are not helpful in identifying fetal acidosis. Since antenatal STV data demonstrated a good predictive potential for fetal acidosis [7], our findings obtained during labor seem rather surprising. What could be the reasons for this discrepancy? First, these authors focused on the situation immediately after delivery by using arterial cord blood parameters. Second, their definition of "fetal acidemia" in the antenatal situation was rather restrictive: the umbilical artery base deficit had to be >12 mmol/L. In addition, the majority of the pregnancies in their study demonstrating short-term FHR variation of <3 ms were identified before 32 weeks with a peak value at 28 weeks. High-risk parameters in pregnancy combined with extreme prematurity were associated with a high incidence of intrauterine death or acidemia as defined by these authors. Therefore, it seems not surprising that the incidence of a short-term variation of <3.0 ms was similarly high.

The design of our study was completely different from that of other authors like Dawes et al. [7]. However, to our knowledge there is no other available study which focused on the relationship between STV and fetal scalp parameters. For comparative reasons, we thought it, therefore, legitimate to discuss the relationship between STV and fetal scalp parameters on the background of a study investigating the correlation between STV and postnatal cord blood parameters. Other striking differences between the two study approaches were gestational age and the approach of investigating the relationship between STV and fetal well-being. We looked for a direct correlation between STV and fetal pH values before birth rather than using a cut-off limit for a very

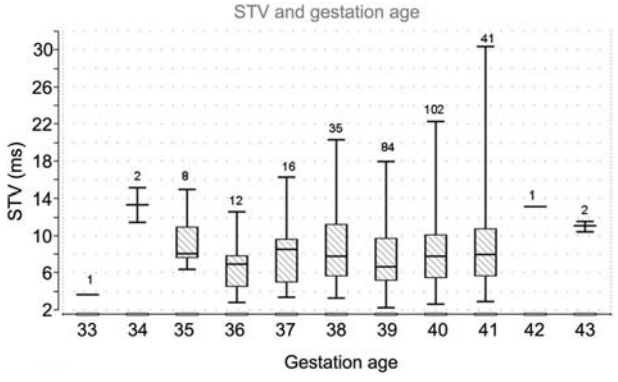

Figure 4 Box-plot of STV and gestation age (median, 1st and 3rd quartile). Numbers of samples are shown above boxes.

critical situation becoming evident after delivery of the child, i.e., at a time when fetal emergency situations have occurred already and cannot be prevented anymore.

In extreme scenarios as described by Dawes et al. [7], fetal compensatory mechanisms do not function any more. That mechanisms for circulatory compensation are rather resistant in mature fetuses, unless an extremely critical lack of oxygen supply occurs, might explain why STVs did not correlate with pH values during labor [14]. Although the fetal scalp base excess was <12 mmol/L in eight cases, none of the newborns examined in our study demonstrated an arterial umbilical cord base excess <12 mmol/L or a pH value <7.0. Therefore, none of the fetuses suffered from an acidemia which persisted until the fetus was born, as in the study situation described by Dawes et al. [7]. According to ACOG view, those fetuses would be expected to have a high risk of cerebral palsy [2]. Mechanisms of circulatory compensation might account for increasing STV values when the oxygen supply slightly decreases. A likely explanation of our findings is that significant changes in STV only occur under extreme conditions i.e., when the fetus is nearly dying, a situation not encountered in our study. Therefore, we doubt that the parameter STV could be used as an early indicator of fetal distress during labor. However, it might be helpful for detecting fetal emergency situations during delivery. Such situations were not observed in the present study. Early obstetrical interventions – as common in our department – might explain the relatively small proportion of fetuses demonstrating signs of severe acidemia.

The low specificity of CTG monitoring during labor and delivery is well known for almost 20 years [25]. Therefore, abnormal CTG results need to be verified using fetal scalp pH measurements [1, 8, 15, 21], a procedure which requires a minimum of cervical dilatation, ruptured membranes and patient compliance. Nevertheless, fetal scalp pH monitoring is considered as "gold standard" to examine the fetal acid base balance and to verify hypoxemia/acidemia [8]. However, if "pathological" fetal heart rate patterns coincide with circumstances which do not allow for fetal scalp pH measurements, a cesarean section often remains the only solution [4].

Computerized analysis of STV of fetal heart rate can be seen as a late step in the search for alternatives to fetal scalp pH measurement. Earlier studies described the use of fetal scalp electrodes and the use of fetal electrocardiograms (ECGs). A computer system (STAN®) is able to calculate the ST-phase and the change of ST-phase during labor. When the CTG was interpreted visually by the FIGO criteria and ST-phase analyses, fetal well-being could be assessed, thereby increasing sensitivity and specificity for fetal acidosis [3, 23].

Roemer et al. [22] showed a correlation of beat-to-beat-variability with postnatal arterial pH-values and base excess, however, no fetal scalp pH values were

taken into account. Correlation coefficients were rather weakly associated with postnatal arterial pH-values and base access values. In our study only two fetal scalp pH values were <7.15, similar to the study group of Roemer et al. who also observed few values of <7.15. Studies showed reduced variability of fetal heart rate by severe fetal acidosis through hypoxic damage of the myocardium [3, 18, 19]. The tendency of a negative correlation of variability (i.e., increased variability) with decreasing pH values might be explained by an adrenaline release due to hypoxic stress [17, 18].

Further studies should examine whether variability of the fetal heart rate during particular times in CTG tracing (e.g., directly after a deceleration) might be a useful objective criterion for fetal acidosis.

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