FETAL HEART RATE CHANGES ASSOCIATED WITH BASELINE T/QRS RISE EVENTS IN ACIDOTIC FETUSES

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REZUMAT

Obiective: evaluarea asocierii dintre valoarea frecvenței cardiace fetale (FCF) și amplitudinea evenimentelor asociate creșterii liniei de bază a T/QRS în cursul nașterii, la fetușii normali și cu acidoză. **Material și metodă:** În cadrul unui studiu retrospectiv, am analizat înregistrările STAN de la fetuși normali (n=33) și cu acidoză (pH <7.05, n=39) la naștere și care au prezentat evenimente ST de tip "baseline T/QRS rise". Valoarea medie a FCF a fost calculată pentru un interval de 2 minute asociat evenimentului ST. S-a identificat, pentru fiecare înregistrare, un segment control al FCF, la 10 minute anterior primeri apariți a evenimentului "baseline T/QRS rise". S-a comparat valoarea medie a segmentului FCF asociat evenimentului ST cu cea a segmentului de control, funcție de amplitudinea creșterii T/QRS, pentru fetușii normali și cu acidoză. **Rezultate:** S-a observat că, o dată cu creșterea liniei de bază a T/QRS, valoarea medie a FCF s-a redus treptat și semnificativ. Această reducere a fost rapidă și profundă la fetușii normali și ușoară, urmată de un platou, până la valuri mari ale T/QRS, la fetușii cu acidoză. Totuși, pentru valori mari ale T/QRS, ambele grupuri au avut valori similare, scăzute ale FCF. **Concluzii:** Variația FCF asociată creșterii liniei de bază a T/QRS este mai puțin pronunțată la fetușii cu acidoză, probabil datorită activării sistemului nervos simpatic. Aceasta poate permite o intervenție adecvată, când sistemele de apărare fetală sunt depășite, dar înainte de creșterea riscului de afectare la distanță.

Cuvinte cheie: frecvență cardiacă fetală, suferință fetală, hipoxie fetală, electrocardiografie, monitorizare fetală

ABSTRACT

Aim of the study: Our objective was to assess the association between fetal heart rate (FHR) and the amplitude of baseline T/QRS rise events during labor in normal and acidotic fetuses. **Material and methods:** Into a retrospective case-control setting, we analyzed STAN traces from acidotic (pH <7.05, n=39) and normal fetuses (n=33) at birth, with baseline T/QRS rise type ST-event in fetal electrocardiogram. Mean FHR was computed over a 2-minute period associated with baseline T/QRS rise event. We described a control FHR segment, 10 minutes before first occurrence of baseline T/QRS rise event. We compared the mean FHR from ST-events, with data from control segment, in relation to the amplitude of T/QRS rise, for acidotic and normal fetuses. **Results:** We found that, during the increase in the baseline of T/QRS, the mean frequency gradually and significantly decreased. This was quick and deep in normal fetuses and small, followed by a plateau, till high T/QRS values for acidotic group. However, for high T/QRS values, both groups had similar decreased values. **Conclusions:** The changes of FHR related to increase of Baseline T/QRS are less pronounced in fetuses dealing with acidosis, probably due to activation of sympathetic system. This should enable us to intervene in the appropriate manner when the fetal defenses have been activated but before there is an increased risk of long-term sequel.

Key Words: fetal heart rate, fetal distress, fetal hypoxia, electrocardiography, fetal monitoring

INTRODUCTION

Birth is one of the hardest trials an individual can experience. The foetus has to adjust to a completely new environment, and, which is more, this transition is associated with hypoxia and acidosis.

The appraisal of the fetal status during labor is a complex procedure, especially due to the limits of the classic cardiotocography (CTG): reduced specificity for hypoxia of the abnormal traces and an increased occurrence of needless obstetrical interventions under the circumstances of continuous monitoring.[1]

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Modern research has developed new methods of intrapartum fetal appraisal. Among them, we can number the STAN system, which is based on the computerized analysis of the ST segment in the electrocardiography (ECG), obtained at the level of the fetal scalp after the rupture of the membranes. This one has a function that automatically identifies the significant changes while the event is announced by the "ST event" messages. There are three standard messages: „episodic T/QRS rise", „baseline T/QRS rise" and „biphasic ST".[2]

The foetus usually presents a relatively stable T/QRS rate during the delivery. Thus, no sharp increases of the ST wave or of the biphasic ST wave appear. The absence of the ST events shows that the foetus controls the situation and that there is a positive energetic balance at the level of the myocardium.

The baseline T/QRS rise is defined as an increase of the T/QRS rate that lasts at least 10 minutes, and whose amplitude is higher than 0.05. It appears when the foetus responds to the persistent hypoxia via an

anaerobic metabolism. As the rate of the glycogenolysis increases, the amplitude of the T wave also increases. Certain healthy foetuses respond to the stress during labor by an increase of the baseline T/QRS associated with a reactive, normal CTG line.

The ST analysis may be influenced by our capacity to record a situation where the foetus defends against hypoxia. Thus, it is possible that the recording starts late, in an existing hypoxic process, when the fetal resources have already been used. In this situation, the T/QRS may be constant, but the aspect of the CTG traces is always abnormal, and is characterized by the loss of reactivity and variability.

Therefore, the identification of the foetuses that have an adaptable response to the labor stress is highly important from the point of view of the intrapartum monitoring. Within this group, one should make the difference between the foetuses that can reach full compensation and, as a consequence, do not run any immediate danger, and those with problems and that use vital metabolic resources for compensation or, are not capable to reach an adequate level of compensation. The latter is the group that may benefit of an intervention in due time, when the fetal defence mechanisms are activated, but before the increase of the long-term injury risk. It is highly recommended that the identification of the foetuses with risk be done by a computerized method of analysis, to increase its accuracy and reduce the variability of the results.

Fetal heart rate (FHR) is the main parameter of the trace and lies at the base of other fetal status assessment techniques, such as the spectral analysis.

Thus, the objective of the present study was to test if the foetuses delivered at term, born with arterial acidosis marked at the level of the umbilical cord will show differences from the point of view of the average FHR, according to the amplitude of the T/QRS rate change, provided by the ST-event function of the STAN system, as compared with the normal group, without acidosis.

MATERIAL AND METHODS

We have analysed the recordings of the FHR provided by the STAN system (Neoventa Medical, Molndal, Sweden), available on the producer's web page (www.neoventa.com), which was achieved within a European, observational survey, developed in several centres, between 2001-2005. These recordings contain both data on the clinical context of the recording, and on the delivery means as well as on the fetal and neonatal state.

Only singleton pregnancies, with a gestational age ≤ 36 of completed weeks at delivery have been selected for this study. At birth, there were no foetuses with major cardiac abnormalities. The recordings with low quality of the electrocardiographic signal have been eliminated.

The study groups have been established according to the value of the arterial pH at the level of the umbilical cord, at birth: the acidotic group with pH < 7.05 (n=33) and the control group with pH ≥ 7.05 (n=39).[3] The clinical data of the two groups and the statistic differences between them are shown in Table 1.

Table 1. Clinical data regarding 33 foetuses with acidosis and 39 normal foetuses (control). The values are expressed as averages if there are no other specifications (p= the statistic signification of the difference between the groups).

	Acidotic fetuses	Control group	p
Gestational age, weeks	39.9 (38 - 42)	39.5 (36 - 42)	0.199*
Weight at birth, g	3695 (2835 - 4410)	3148 (2030 - 4040)	<0.001†
% of caesarean sections	27.3	25.6	0.876 §
Apgar rate after 5 minutes	6.2 (0 - 10)	9.1 (5 - 10)	<0.001*
Arterial pH from the cord	6.92 (6.61 - 7.03)	7.13 (7.05 - 7.29)	<0.001†
Basic deficit arterial cord, mmol/l	12.6 (6.45 - 19.10)	6.56 (-16.50 - 13.5)	<0.001†

* ANOVA one-way test, † two-sample t test, § χ^2 test.

Recommendations for interpretation of the STAN recordings and distribution of the T/QRS amplitude histogram (delta T/QRS) have led to its classification within the study, into the following groups: <0.07, 0.07 – 0.09, 0.1-0.15 and ≥ 0.15.[2]

Values of the FHR, T/QRS and its significant changes (ST event) within the STAN intrapartum recordings have been read and analysed by a programme developed in Matlab (MathWorks Inc., USA). It identifies, within the recording, the moments of the stable increase of the baseline T/QRS, announced by the ST-event of the STAN system through the message "baseline T/QRS rise". The programme subsequently uses the time indicated by the ST-event as a reference moment for the selection of a FHR segment of 120 seconds for analysis. The FHR segment is selected previously (to the left) to the ST event.

The duration of these FHR segments was chosen thus because it guarantees the compatibility of the results with other similar studies; the STAN system uses a time window of the same size; the outcome is an optimum number of temporary values of the FHR; a higher value would lead to more segments with high signal losses and the duration is comparable to that of the uterine phenomena at the end of the first and of the second delivery stage.[3,4]

The STAN system recognizes the changes of the T/QRS amplitude („baseline T/QRS rise") comparing

with a reference segment situated ten minutes back in time. For these reasons, within this study, a reference FCF segment, situated at least 10 minute distance, has been automatically selected using a special algorithm.

Thus, the FHR reference segment is identified at the first occurrence of the „baseline T/QRS rise" message, within the respective recording. If during a STAN recording there is a progressive increase of the T/QRS rate indicated by the "baseline T/QRS rise" message, then for each similar ST event, the reference segment will be FHR segment identified on the first occurrence of the event. If during a STAN recording for the „baseline T/QRS rise" messages, the T/QRS rate remains constant, or if after a progressive increase this rate decreases, and these events occur at more often than at every other 10 minutes, the system calculates a new reference segment. (Fig. 1)

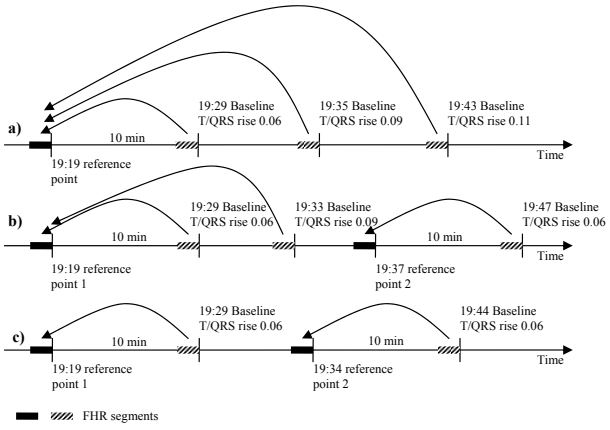

Figure 1. The choice of the reference system: a) a single initial segment in the case of a progressive increase of the T/QRS; b) and c) the change of the reference segment if the T/QRS rate decreases or remains constant, while the events occur at a distance of more than 10 minutes.

In case of FHR segments with >5% missing data, we have used a 120 seconds mobile window that moves back in time (to the left), on a distance of maximum 180 seconds, until we get a FHR segment of an adequate quality. The average value of the FHR on the selected segments has been calculated.

The longitudinal change of the FHR was compared using the analysis of variances (Levene) and the Student t test for independent groups, where the grouping factor (acidotic or control) was an independent variable. The normal distribution of the data was analyzed via the Kolmogorov-Smirnov test, and where necessary, the data have been transformed by logaritmation for the statistic analysis.

The clinical data have been interpreted using the t Student test, ANOVA or χ^2, according to the situation. The results are expressed as average ± standard or average error (change period), while $p < 0.05$ were thought to be significant. The statistic analysis was achieved with the SPSS program 12.0 for Windows (LEAD Technologies).

RESULTS

The programme developed in Matlab has identified 82 intrapartum STAN recordings with 296 „baseline T/QRS rise" events. Finally, the elimination of the FHR segments with a signal loss which is >5% had led to 242 events (81.8%), coming from 82 STAN recordings. Therefore, through this method we do not have eliminated recordings, but only certain ST events within these recordings. Table 2 shows that the eliminated segments are closer to the end of the STAN recordings (the signal loss is higher during the 2nd stage of the delivery) and have a lower average FHR value. Still, which is most important, there are no differences from the point of view of the average change of the T/QRS rate (delta) and of the appraisal parameters of the foetal state (Apgar ranking after 1 and 5 minutes, the pH and the basic deficit at the level of the umbilical artery).

Table 2. Clinical data from the FHR segment groups with signal loss ≤ 5% and > 5% (mean ± SE) (p= statistic difference between the groups, t Student test).

	Signal loss ≤5% (n=242)	**Signal loss >5% (n=54)**	**p**
Delta T/QRS	0.094±0.003	0.105±0.006	0.141
Time until birth (s)	3996±397	1161±342	**0.000**
Average FCF (bpm)	129.6±1.5	121.9±3.8	**0.036**
Arterial pH	7.01±0.008	7.01±0.019	0.864
Arterial BDecf	10.4±0.4	9.8±0.8	0.476
Apgar 1 min	5.1±0.2	5.8±0.4	0.081
Apgar 5 min	7.3±0.2	7.9±0.3	0.073

BDecf = Arterial Cord Base Deficit, mmol/l

72 cases were available for investigation after the elimination of the incomplete data or of the high signal loss FHR segments. The group with acidosis at birth (arterial pH <7.05, n=39 have shown 116 STAN events for which the system has selected 64 reference segments, while the control group (pH ≥7.05, n=33) provided 97 STAN events, and 57 reference segments.

The distribution on study periods of the amplitude of T/QRS rate change was similar within the two groups, with acidosis and control. (Fig. 2)

We have found that together with the increase of the T/QRS rate change during delivery, the average FHR decreases progressively, significantly more rapidly and powerfully in the normal group as compared to the pH<7.05. (Table 3)

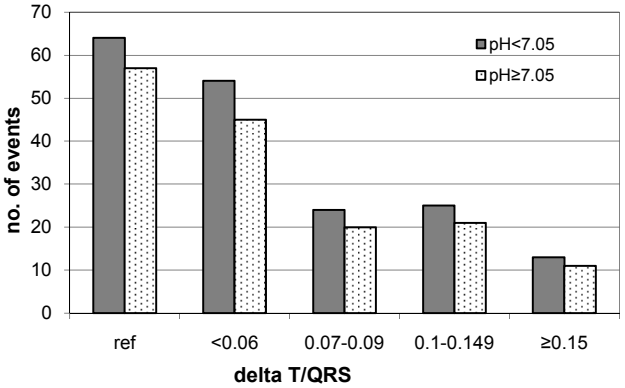

Figure 2. Distribution of the „baseline T/QRS rise" STAN events, for intervals of T/QRS variation, for both groups (with acidosis and control) (Ref. = the group of the reference FHR segments).

Table 3. Statistic significance (p) of the difference, for the average value of the FHR, between the variation groups of the T/QRS amplitude and the groups of the reference FHR segments, for both the group with acidosis and for the control one (t test for two independent variables).

	≤0.06 vs. ref	0.07-0.09 vs. ref.	0.1-0.149 vs. ref.	≥0.15 vs. ref
pH<7.05	**0.019**	0.10	0.24	**0.0001**
pH≥7.05	**0.002**	**0.03**	**0.003**	**0.01**

ref. = the group of reference FHR segments.

Thus, the decrease of the average FHR as compared to the values of the FHR reference segment is important for the first moments of the (delta ≤0.06) T/QRS increase, but it is significantly lower for the acidosis group as compared to the control one. Subsequently, along with the T/QRS increase, the average FHR behaves differently for the two groups of fetuses. The acidosis group manifests a slight increase tendency (difference that is not statistically important) up to higher values of the T/QRS (delta ≥ 0.15) when the average FHR collapses, reaching similar values to those of the control group. (Fig. 3) For the control group (pH ≥ 7.05), one can notice a rather slower decrease of the average FHR along with the T/QRS increase, but progressive and statistically significant.

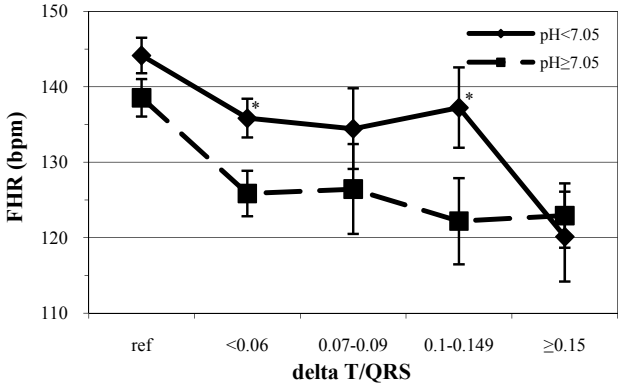

Figure 3. Mean FHR (mean±SE), on groups of T/QRS rate increase, during delivery, in fetuses with acidosis (pH<7.05) and in control fetuses (pH ≥7.05). *= significant difference between the groups (p<0.05, test t for two independent groups); ref = the group of reference FHR segments; bpm = beats per minute.

CONCLUSIONS

The programme has correctly identified the STAN events given by the ST-event in the intrapartum fetal ECG recordings. As well as this, it has associated the STAN events with the FHR segments facilitating their analysis.

The increase of the baseline T/QRS appears when the fetus responds to hypoxia by an anaerobic metabolism, when there is a persistent factor of stress and no recovery period. There is still a group of healthy fetuses that answer to the stress during labor with an increase of the baseline T/QRS, associated with a reactive, normal CTG line.[2,5] A 2003 randomized trial confirmed the capacity of the automatic analysis of the fetal ST segment of signaling the circumstances in which hypoxia and acidosis develop, thus reducing noticeably the risk of fetal injury.[6] Our study highlights, for the first time, the association between the T/QRS rate change during labor (emphasized by the "baseline T/QRS rise" message), and the average value of the FCF in the respective recorded segments.

To study the way in which the FHR is influenced by marked acidosis, we have chosen as the threshold, the pH of 7.05 at the level of the umbilical cord. This level of the acidosis exposes the fetus to a significant risk of neonatal symptomatology occurrence.[6-8]

We have noticed a decrease of the average FHR from the first moments of the baseline T/QRS increase (≤0.06). Still, this decrease, although statistically significant, was less noticed in fetuses with acidosis at birth. This group continued to behave differently under T/QRS increase, having a relatively constant mean and variability of FHR, with an increasing tendency, even significantly higher than the normal group. Moreover, under extreme increases of T/QRS, the FHR parameters of the group with acidosis drop importantly, reaching similar values to those of the control (normal) group.

Other studies show an increase of the T/QRS rate in fetuses with acidosis.[2,5,9] This ST feature is associated with an increase in the activity of the β adrenergic receptors and adrenaline discharge, which also explains the increase of the average FHR.[10,11]

The described phenomena are similar to those observed by Siira et al., who have also noticed an increase of the basal FHR and of the variability in fetuses with acidosis, as compared to the control group, followed by a decrease before birth.[3] Still, these changes are analyzed only during the last labor hour and are not compared with a reference FHR segment. The study uses the manual selection of the analyzed FHR segments.

In human fetus, the acute hypoxia determines a slight increase of the FHR, but in severe acidosis, the FHR drops, leading to bradycardia.[12,13]

In our study, the marked decrease of the extreme FHR value of the T/QRS (≥0.15) observed in fetuses with acidosis at birth may stand for an initial sign of the circulatory decompensation. This is supported by the evolution, during labor, of the fetuses with respiratory acidosis that do not present this drop at high values of the T/QRS (unpublished data).

Thus, we may assume that under the circumstances of the increase during labor of the T/QRS value, a fetus with a good prognosis will show a decrease of the average FHR. If this decrease does not take place, or there is only a temporary drop, the fetus uses the energetic resources via an extremely intense adrenergic activity. If this phenomenon persists until birth we have a relatively better prognosis (respiratory acidosis). A reserved prognosis (metabolic acidosis) is given when the fetus either reacts less intensely to thee labor stress, due to more reduced energetic reserves or to unknown causes, or uses up the energetic reserves and reaches decompensation, which is marked by the important decrease of the FHR and of its variability.

In conclusion, the results of this study suggest that the decrease of the average FHR, measured on 2-minute segments, reveal the problems of the autonomous cardiac control in mature fetuses that respond to stress during labor. However, the number of fetuses with acidosis was relatively small for us to be able to draw conclusions which could be clinically applied. The current data uphold the feasibility of the automatic appraisal of FHR for the interpretation of the intrapartum complex traces.

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