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Do spectral bands of fetal heart rate variability associate with concomitant fetal scalp pH?

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ABSTRACT

Background: Objective information on specific fetal heart rate (FHR) parameters would be advantageous when assessing fetal responses to hypoxia. Small, visually undetectable changes in FHR variability can be quantified by power spectral analysis of FHR variability.
Aims: To investigate the effect of intrapartum hypoxia and acidemia on spectral powers of FHR variability.
Study design: This is a retrospective observational clinical study with data from an EU multicenter project.
Subjects: We had 462 fetuses with a normal pH-value (pH > 7.20; controls) in fetal scalp blood sample (FBS) and 81 fetuses with a low scalp pH-value (≤7.20; low-FBS pH-fetuses). The low-FBS pH-fetuses were further divided into two subgroups according to the degree of acidemia: fetuses with FBS pH 7.11–7.20 (n = 58) and fetuses with FBS pH ≤7.10 (n = 23).
Outcome measures: Spectral powers of FHR variability in relation to the concomitant FBS pH-value.
Results: Fetuses with FBS pH ≤7.20 had increased spectral powers of FHR variability compared with controls (2.49 AU vs. 2.23 AU; p = 0.038). However, the subgroup of most affected fetuses (those with FBS pH ≤7.10) had significantly lower FHR variability spectral powers when compared to fetuses with FBS pH 7.11–7.20.
Conclusions: This study shows that spectral powers of FHR variability change as a fetus becomes hypoxic, and that spectral powers decrease with deepening fetal acidemia.

1. Introduction

Detection of fetal asphyxia during labor and delivery is challenging. A normal and reactive cardiotocography (CTG) indicates no obvious danger of fetal asphyxia. However, an abnormal intrapartum CTG pattern predicts fetal acidemia in less than one-third of the cases [1]. In the case of a nonreassuring CTG, a fetal scalp blood sampling (FBS) is recommended to detect intrapartum acidemia [2]. However, FBS gives only momentary information and often needs to be taken repeatedly. FBS is thus time-consuming and inconvenient to the parturient and may lead to complications, e.g. fetal scalp infection and hemorrhage [3,4].

ST analysis of the fetal electrocardiogram (ECG) is used in combination with CTG (STAN®) to assess fetal well-being during delivery. Compared to FBS, ST-analysis yields continuous information and is more convenient for the parturient. However, the STAN® methodology is dependent on the interpretation of the CTG, which has high inter- and intraobserver variability, especially on nonreassuring FHR tracings [5]. Thus, more objective information on specific FHR parameters would facilitate the detection of fetal hypoxia.

Power spectral analysis of FHR variability is an objective tool for quantifying small, visually undetectable changes in FHR variability. Previous studies on intrapartum FHR variability measured with power spectral analysis have mainly assessed changes of FHR variability in relation to cord acid–base values measured after birth. The aim of the present study was to investigate the effect of intrapartum hypoxia and acidemia (defined by FBS pH-value) on spectral powers of FHR variability.

2. Materials and methods

The original data consisted of 812 fetuses with FBS taken and intrapartum ECG (R–R interval data) recorded as a part of an EU multicenter project on intrapartum fetal monitoring with the STAN® method [6]. From these data, those fetuses (n = 543) having good quality (e.g. no large breaks) ECG recorded 15 min prior to last FBS

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were included. Fetuses with major cardiac or extra-cardiac malformation were excluded. Duration of pregnancies exceeded 36 weeks of gestation. Ethical approval and informed consent were obtained in those centers where STAN® was not being used as part of standard care.

FHR variability data was divided according to the scalp blood pH-value: Fetuses with scalp pH > 7.20 (n = 462, controls) and fetuses with scalp pH ≤ 7.20 (n = 81, low-FBS pH-fetuses). Scalp pH ≤ 7.20 is regarded as a sign of increased risk of acidosis [12], and was thereby selected as a cut-off value. The low-FBS pH-fetuses were further divided into two subgroups: fetuses with FBS pH 7.11–7.20 (n = 58) and fetuses with FBS pH ≤ 7.10 (n = 23). A flow chart on the process of selection of cases is presented in Fig. 1.

2.1. Data acquisition and signal processing

Fetal ECG was recorded during delivery with an intrauterine scalp electrode using a STAN® S21 monitor (Neoventa Medical, Moelndal, Sweden). Fetal unipolar ECG lead configuration consisted of a single-helix scalp electrode and a maternal skin electrode. R-peaks were detected, and R–R intervals were measured and digitized at a sampling rate of 500 Hz. The R–R interval data sets were stored digitally as part of STAN® data archiving, and the intervals from the study period were analyzed off-line.

2.2. Spectral analysis

FHR variability was quantified with spectral analysis as previously described [7–9]. Power spectral analysis was performed in two-minute signal segments for a period of 14 min (7 × 2 min) preceding the FBS.

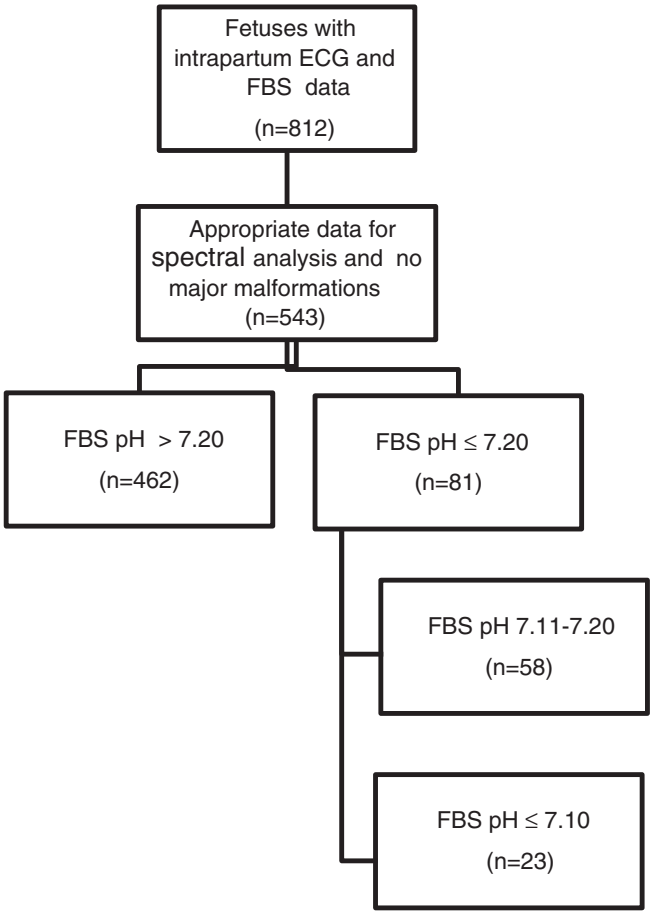

Fig. 1. A flow chart on the process of selection of cases. ECG = electrocardiogram, FBS = fetal scalp blood sample.

On average, four continuous two-minute signal segments were obtained, and the mean spectral power of these segments was calculated. The quality of these signal segments was checked by a signal analyst, and data analysis was performed with no knowledge of the clinical data. In the case of large signal breaks in the two-minute R–R data segments, a new segment was started immediately after a break to minimize loss of data. The R–R interval data sets were transformed to a continuous digital signal by linear interpolation, and then the event series was resampled at the rate of 16 Hz. The reciprocal of each R–R interval was computed to obtain the respective instantaneous heart-rate reading. Fast-Fourier-transformed power spectra were then computed for the FHR signal segments (MATLAB®-oriented tailor-made signal-analysis program, MARAPS, Tampere, Finland) [10].

The FHR variability spectrum was integrated over the total frequency band (0.04–1.0 Hz), as well as over the low-frequency (LF) band from 0.04 Hz to 0.15 Hz (from 2.4 to 7.8 cycles/min) (corresponding mainly to sympathetic and parasympathetic control), and over the high-frequency (HF) band from 0.15 Hz to 1.0 Hz (from 7.8 to 60 cycles/min) (corresponding to parasympathetic control) [11]. To minimize the effect of FHR on FHR variability, we calculated the coefficient of component variance (square root of power spectra / mean R–R interval) [12]. Low-to-high frequency ratio (LF/HF) was assessed to display the balance of sympathetic and parasympathetic control [11]. All the spectral variability data are given in arbitrary units (AU).

2.3. Statistical methods

The results were statistically analyzed by SAS System for Windows, release 8.01 (SAS Institute, Cary, North Carolina, USA). The continuous variables in the clinical data were analyzed with a Student's two-sample test or a Wilcoxon two-sample test, as appropriate. The proportion of operative deliveries between groups was compared with a chi-square test. Because of a skewed distribution of data, FHR variability values were square-root-transformed. The results are expressed as mean (range), median [range] or number (percentage, %), as appropriate. The associations between spectral bands and FBS pH were analyzed with the Spearman correlation coefficient. Because gestational age is known to affect FHR variability [13,14], the partial correlation coefficient between spectral bands and the FBS pH was also calculated by adjusting correlation for gestational age as a covariate. The differences of spectral bands between subgroups were tested with two sample *t*-test. A p-value <0.05 was considered significant.

3. Results

Clinical data from the studied fetuses are presented in Table 1. Low-FBS pH-fetuses revealed, as expected, more operative deliveries, and had shorter time lag from FBS to birth.

Overall FHR variability was higher in low-FBS pH-fetuses when compared with control fetuses (p = 0.038; Fig. 2). However, the subgroup of most-affected fetuses (those with FBS pH ≤ 7.10) had significantly lower FHR variability spectral powers when compared to fetuses with FBS pH 7.11–7.20 (p = 0.047; Fig. 2). No differences in LF/HF ratio were found between the study groups (data not shown).

In low-FBS pH-fetuses, overall spectral powers of FHR variability had weak positive correlation with FBS pH (total power; r = 0.29, p = 0.008), whereas the correlation was poor and negative in fetuses with FBS > 7.20 (total power; r = −0.15, p = 0.001). In these groups, LF and HF spectral powers did not correlate any better with FBS pH. However, in fetuses with FBS pH ≤ 7.10, HF spectral powers of FHR variability correlated (r = 0.498; p = 0.018) with FBS pH. Adjusting correlations for gestational age had no effect on the results.