Original Article

Fetal Non-invasive Electrocardiography Contributes to Better Diagnostics of Fetal Distress: A Cross-sectional Study Among Patients with Pre-eclampsia

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Abstract

Introduction: Fetal distress is a result of acute or chronic disturbances in the system of "mother-placenta-fetus" in pre-eclampsia (PE). The aim of the investigation was to compare the accuracy of antenatal fetal distress diagnostics in cases of traditional cardiotocography (CTG) waveform evaluation and analysis of morphological non-invasive electrocardiogram (ECG) parameters in anterpartum patients with PE. Materials and Methods: Fetal non-invasive ECG antenatal recordings of 122 pregnant patients at 34 to 40 weeks of gestation were examined. In Group I, there were 32 women with physiological gestation and normal fetal condition according to haemodynamic Doppler values. Group II involved 48 patients with mild and moderate PE whom were performed Doppler investigation. In Group III, 42 patients with severe PE were monitored with haemodynamic Doppler. Results: Fetal autonomic tone was lower with the relative increase of low frequency (LF) branch in the patients of pre-eclamptic group. The increased value of the amplitude of mode (AMo) and stress index (SI) was associated with adrenergic overactivity. It has induced pQ and QT shortening, increased T/QRS ratio and decelerations appearance. The rate of antenatal fetal distress retrospectively was 31.1 % in PE. The traditional analysis of CTG parameters has showed sensitivity (72.7%) and specificity (87.1%). In addition to the conventional CTG analysis, evaluation of ECG parameters has contributed to better diagnostics of fetal distress. Sensitivity and specificity of non-invasive fetal ECG were absolutely equal in this study (100%). Conclusion: The results suggest that fetal non-invasive ECG monitoring is more objective than conventional CTG.

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Key words: Fetal heart rate variability, Fetal monitoring, Hypertensive disorders of pregnancy

Introduction

Autonomic nervous regulation spreads its influence on fetal heart rate, creating cardiac rhythm complexity. Fetal heart rate has a multifractal nature that is largely connected with its biophysical activity.[1-5] Heart rate variability (HRV) is a convenient instrument of investigation in the field of neurodevelopment. The spectral analysis of HRV could determine the origin of oscillations in the sinus node. Fetal autonomic response on intrauterine activity is associated with an increase in total power (TP) of HRV. Fetal motile activity is also reflected in augmented power of low frequency (LF) and very low frequency (VLF) domains of HRV.[4,5] LF component is used as a marker of sympathetic activity.[1] VLF is traditionally associated with the function of hypothalamic-pituitary-adrenal axis. Fetal vagal-mediated reactions are located in high frequency (HF) region of HRV. During "sleep-rest" periods, fetal HRV pattern demonstrates decreased TP and all its fractal components.[2,4]

Traditional ultrasonographic cardiotocography (CTG) tracing is not absolutely specific for fetal well-being assessment.[6] The detection of primary bioelectrical processes obtained from maternal abdominal wall with non-invasive fetal electrocardiography (ECG) could provide the higher precision of CTG waveform. The HRV values have

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a very wide range and rather complicated interpretation.[7-9] Additional investigation of the fetal ECG parameters could contribute to the advancement of the fetal functional state diagnostics. Previously, the validity of several relative values: P/R, P/Q, R/S, R/T, PR/RR and T/QRS was investigated. And T/QRS has gained most popularity in distress diagnostics.[10,11] It is known that increased T/QRS ratio because of the elevated T wave is anaerobic myocardial metabolism marker.[6,10] Recent investigations have provided the information that fetal hypoxia could cause the shortening of QT interval.[8]

The main experience in fetal ECG morphological parameters assessment is associated with magnetocardiography.[11,12] This method incurs high cost and therefore is not in routine use now. The Monica AN24 monitor gave the possibility to use fetal non-invasive ECG but it wasn't still widely available.[9] Ukrainian scientists developed the Cardiolab Babycard fetal non-invasive ECG monitor lately. The quality of the Ukrainian ECG recordings were tested by international experts.[13]

Pre-eclampsia (PE) is a pregnancy-associated disease found only in humans. PE induces systemic changes of maternal haemodynamics due to the failure of utero-placental circulation.[14] It has also shown to cause considerable fetal compromise in pregnancy.[1-3] The aim of the investigation was to compare the accuracy of antenatal fetal distress diagnostics in case of traditional CTG waveform evaluation and analysis of morphological non-invasive ECG parameters in anterpartum patients with PE.

Materials and Methods

The study protocol was approved by the bioethics committee of the Medical Academy of Postgraduate Education. Observed pregnant patients were informed about the methods of the study, its aim, indications and eventual complications before inclusion in the study. All patients gave written informed consent to participate in the investigation. The study was conducted over a period of 2 years from September 2011 to December 2013. The inclusion criteria were: diagnosis of PE based on a blood pressure of more than 140/90 mm Hg on 2 separate occasions 6 hours apart; and positive proteinuria test in 2 midstream urine samples collected 4 hours apart. The exclusion criteria were: multiple pregnancy; eclampsia; and pre-existing medical disorders such as diabetes mellitus, cardiac diseases, renal disease, thyrotoxycosis, chronic hypertension, and uterine contractions (threatened preterm labour).

Fetal non-invasive ECG antenatal recordings of 122 pregnant patients at 34 to 40 weeks of gestation were examined. Patients were divided into 3 groups randomly. In Group I, there were 32 women with physiological gestation and normal fetal condition according to fetal non-invasive ECG and haemodynamic Doppler values. Group II involved 48 patients with mild and moderate PE whom were performed fetal non-invasive ECG monitoring and Doppler investigation. In Group III, 42 patients with severe PE were monitored with fetal non-invasive ECG and haemodynamic Doppler.

Fetal ECG parameters were obtained with the application of the fetal non-invasive ECG monitor Cardiolab Babycard (Kharkiv, Ukraine). The registration was carried out over 10 minutes. The value of TP and its spectral compounds (VLF, LF and HF) were estimated. The temporal characteristics of the fetal HRV: standard deviation of normal to normal intervals (SDNN), root mean square of successive differences (RMSSD), the proportion of the number of pairs of successive NNs that differ by more than 50 ms divided by total number of NNs (pNN50), the amplitude of mode (AMo) and stress index (SI) were determined. The CTG waveform analysis was performed with short-term variability (STV) and long-term variability (LTV) scoring. The fetal ECG parameters such as pQ, QT intervals and QRS complex duration, T wave amplitude, T/QRS ratio were calculated. The share of instrumentally determined fetal distress in antenatal period and Apgar score after delivery was examined.

The results were processed by parametric statistical methods (mean-M, error-m) with the application of statistics software package Excel adapted for biomedical research. The results thus obtained were subjected to standard statistical analysis and analysed using the Chi-square test to compare for categorical data between the groups. The significance was set at $P < 0.05$. For the statistical analysis of relationship between X and Y, correlations coefficients were estimated using Spearman's test. Additionally, the sensitivity and specificity of diagnostic tests were calculated.

Discussion

The obtained data demonstrates the significant difference in fetal HRV parameters in the study groups of patients (Table 1). It is determined that TP and SDNN values were decreased in direct proportion to the severity degree of PE. So fetal autonomic tone was lower with the relative increase of LF branch in the patients of Group II and Group III. The predominance of the central sympathetic baroreflex mediated regulation of fetal hemodynamic was the main event in the PE induced scenario. This tendency was stable and showed the abnormally augmented sympathetic tone in severe PE. The revealed peculiarity was associated with almost completely lost autonomic control of cardiac activity and the fallen level of heart rhythm complexity. The increased values of AMo and SI were associated with

Table 1. Fetal HRV Parameters in the Patients

Index, Units of Measure	Group I	Group II	Group III
SDNN, ms	50.5 ± 9.4	30.6 ± 6.8*	24.6 ± 8.4*†
RMSSD, ms	22.3 ± 6.2	14.2 ± 3.5*	8.0 ± 2.4*†
pNN5O, %	8.7 ± 2.1	5.7 ± 0.9*	3.5 ± 0.6*†
SI, conv. units	140.6 ± 31.3	654.8 ± 143.5*	1436.8 ± 321.4*†
AMo, %	38.2 ± 12.9	55.8 ± 16.4*	62.5 ± 19.1*†
TP, ms²	1634.8 ± 364.5	1048.4 ± 126.2*	534.2 ± 81.3*†
VLF, ms²	1346.2 ± 282.8	670.2 ± 84.6*	349.2 ± 23.8*†
LF, ms²	192.6 ± 31.1	312.2 ± 66.8*	148.6 ± 25.1*†
HF, ms²	95.2 ± 19.4	66.1 ± 14.9*	37.2 ± 14.1*†
STV, ms	8.6 ± 2.0	6.2 ± 1.4*	3.9 ± 1.2*†
LTV, ms	38.0 ± 9.4	26.4 ± 5.3*	17.2 ± 8.8*†

*The differences were statistically significant compared to the control group (P <0.05).
†The differences were statistically significant compared to the group II (P <0.05).
SDNN: Standard deviation of normal to normal intervals; RMSSD: Root mean square of successive differences; pNN50: The proportion of the number of pairs of successive NNs that differ by more than 50 ms divided by total number of NNs; AMo: The amplitude of mode; SI: Stress index; TP: Total power; VLF: Very low frequency; LF: Low frequency; HF: High frequency; STV: Short-term variability; LTV: Long-term variability

abnormal myocardial adrenergic stimulation and were similar to the adult patients with acute coronary desease.[3] It is speculated that the origin of the antenatal deceleration was presented in the pronounced augmentation of the sympathetic baroreflex. The mean value of short-term mediated parameters RMSSD, pNN5O, HF and STV was decreased in mild-moderate and severe PE. The supression of respiratory sinus arhythmia was the predisposing condition to rigid rhythm formation. The lack of fetal vagal regulation was determined in patients with PE. In several cases, it was determined by the mutual adrenergic and vagal activation. It is possible to hypothesise that hyperactivity of adrenergic regulation could stimulate meconium passage and latter inspiration during episodes of respiratory activity. The speculation that aspiration syndrome could originate on the basis of the above mentioned autonomic disturbances needs further investigation.

The pQ measurement demonstrated gradual evolution (Table 2). The onset of the fetal deterioration was initiated by humoral adrenergic substances and is reflected in tachycardia. An increased fetal heart rate has its manifestation in the prolonged pQ.[9,10,12] The further baroreflex activation changed fetal heart rate to the lower score. The decelerations and bradycardia have shortened pQ intervals. The deceleration pattern of CTG waveform in several patients in Group II and Group III was accompanied with significant pQ shortening. So the decrease of pQ was a mirror of decelerations. A QT reduction could be a marker of anaerobic myocardial metabolism and fetal distress. The lowered QT length and the rise of T wave amplitude are symptoms of β-adrenergic receptors activation.[8,10-12] The affected myocardium has reacted with high T/QRS ratio.

The investigation of statistically significant correlations between newborn Apgar score 1 and fetal HRV, CTG and non-invasive ECG parameters has revealed certain regularities (Fig. 1). The most considerable negative correlation was determined in pair Apgar score 1 versus T/QRS (R = -0.46; P <0.05). So the increased T/QRS ratio was the most valuable

Table 2. Fetal ECG Parameters in the Patients

Index, Units of Measure	Group I	Group II	Group III
pQ, ms	101.2 ± 16.4	105.4 ± 14.3*	95.8 ± 20.4*†
QT, ms	222.4 ± 29.6	198.6 ± 25.4*	195.0 ± 23.9*†
QRS, ms	144.8 ± 8.6	145.6 ± 10.4	65.8 ± 0.2*†
T, mcV	2.6 ± 0.4	4.5 ± 0.6*	8.2 ± 2.1*†
T/QRS	0.04 ± 0.01	0.07 ± 0.02*	0.15 ± 0.04*†

*The differences were statistically significant compared to the control group (P <0.05).
†The differences were statistically significant compared to the group II (P <0.05).

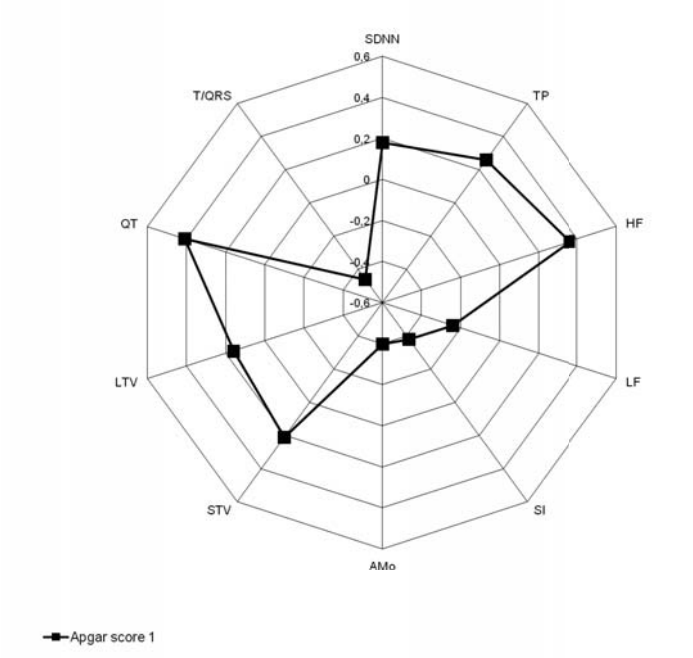

Fig. 1. Correlations between Apgar score 1 and values of HRV, CTG and morphological ECG parameters in the study population.

marker of antenatal distress. The QT interval duration has revealed positive correlation with Apgar score 1 (R = 0.41; P <0.05). The validity of fetal HRV parameters was quite different. The negative correlation was determined between Apgar score 1 versus SI (R = -0.38; P <0.05) and Apgar score 1versus AMo (R = -0.40; P <0.05). So AMo and SI were independent from fetal stationary status and could be considered as specific reflection of fetal compromise. It was not determined a considerable relationship between SDNN versus Apgar score 1 (R = 0.18; P <0.05) and TP versus Apgar score 1 (R = 0.26; P <0.05). It was obvious that autonomic tone has a weak connection with fetal distress. Fetal vagal tone has revealed a correlation with Apgar score 1 (R = 0.36; P <0.05). The negative correlation between fetal sympathetic tone and Apgar score 1 has been determined (R = -0.24; P <0.05). The parameters of CTG has demonstrated weak correlation with Apgar score 1: STV (R = 0.21; P <0.05) and LTV (R = 0.16; P <0.05). The obtained data confirms speculation that fetal non-invasive ECG parameters are very valuable in antenatal distress diagnostics.

The rate of antenatal fetal distress retrospectively was 31.1% in PE. This result was rather logical.[3] The traditional analysis of CTG parameters has showed sensitivity—72.7% and specificity—87.1%. In addition to the conventional CTG analysis, evaluation of ECG parameters has contributed to better diagnostics of fetal distress. Sensitivity and specificity of non-invasive fetal ECG were absolutely equal in this study (100%). It has made it possible to make a small step in the march toward fewer caesarean deliveries in the era of advanced electronic fetal monitoring. In Figure 2, a prolonged deceleration with a decrease of basal heart rate is seen in a conventional CTG. In patients with PE, it is typical to think about fetal distress and becoming more active. But the mean value of T/QRS ratio is 0.036 ± 0.002. The range of normal values of T/QRS is up to 0.26.[10] So in this case, we have to wait and repeat the ECG monitoring later.

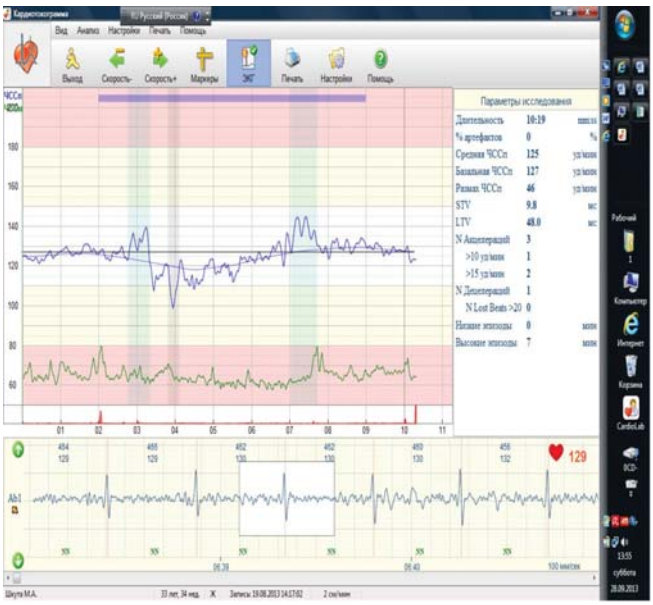

Fig. 2. The "window" in Cardiolab Babycard programme (3 accelerations and single deceleration to 100 beats per minute).

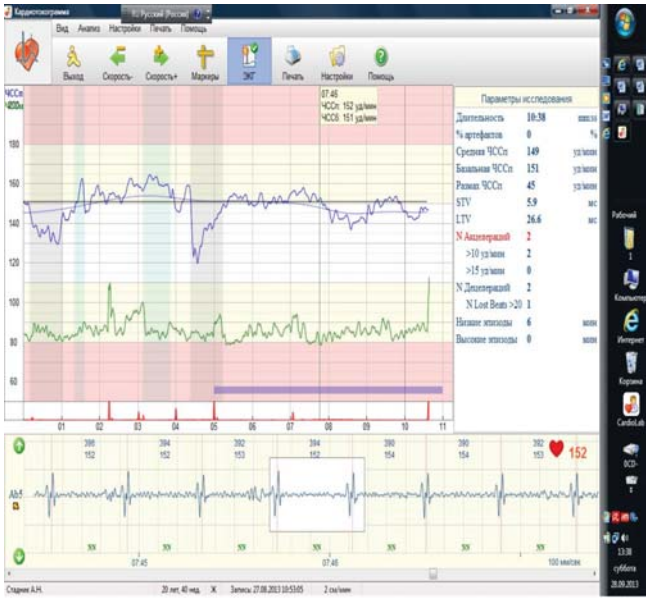

Fig. 3. The "window" in Cardiolab Babycard programme (2 accelerations and 2 decelerations on CTG pattern).

The result was spontaneous vaginal delivery with Apgar score 7-8. Another patient from Group II demonstrated uncertain type of CTG pattern because of 2 low amplitude accelerations and 2 decelerations within a normal heart rate (Fig. 3). The slightly elevated ST segment and determined amplitude of T peak were associated with mean T/QRS ratio 0.096 ± 0.004. It was a marker of normal fetal condition. In this case, an urgent caesarean section was performed because of cefalo-pelvic disproportion in labour. The Apgar score was 8-9. So fetal non-invasive ECG allows for better diagnostics of fetal distress.

The results show that fetal non-invasive ECG monitoring is more objective than conventional CTG and convenient in urgent situations. ECG investigation is absolutely safe for the fetus and can be performed as a Holter monitoring. Its compatibility with modern wireless communication facilitates the creation of systems for remote fetal monitoring. It is a practical consideration for the fetal surgery department and is timely to introduce it widely in perinatology.

Conclusion

Decreased fetal autonomic tone and augmented sympathetic regulation were marked in PE and were associated with pQ and QT shortening, increased T/QRS ratio and decelerations in appearance. Considerable correlation between the Apgar score 1 and fetal T/QRS ratio was found. Fetal non-invasive ECG was found to have equal sensitivity and specificity in this study (100%) and therefore is a more objective and convenient method for fetal monitoring than conventional CTG.

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