electrohysterography,
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THE PROGNOSTIC VALUE OF ELECTROHYSTEROGRAPHY IN PREDICTION OF PREMATURE LABOUR

Premature birth is the leading cause of a neonatal death, so, it is extremely important to distinguish the pregnancy at risk of preterm threatening labour. The electrohysterography seems very promising as a method which enables noninvasive recording of readable bioelectrical signal of uterine muscle. The developed instrumentation enabled simultaneous recording of bioelectrical signals by means of electrodes attached to abdominal wall and mechanical activity of uterine muscle using fetal monitor. Material comprised 27 patients in physiological pregnancy (27 ÷ 40 week), and 21 patients (23 ÷ 36 week) with the symptoms of threatening premature labour. The obtained results showed that quantitative parameters of detected uterine contractions: amplitude and contraction area, obtained both for mechanical and electrical activity, were statistically significant ($p < 0.05$) to distinguish the patients at risk of premature labour. However, their reliability is low because they strongly depend on individual patient features. We consider the parameters characteristic for electrohysterogram exclusively e.g. contraction power and its median frequency as more useful ($p < 0.05$). Noninvasive electrohysterography ensures higher sensitivity and specificity for recognition of uterine contraction activity in comparison to classical mechanical method.

1. INTRODUCTION

Premature birth is the leading cause of a neonatal death. Therefore, it is extremely important to distinguish the high-risk pregnancy group comprising pregnant women at risk of premature uterine contraction activity. As it has been confirmed in clinical practice, the classical external tocography is not sufficient for precise discrimination of patients at risk of premature labour. Thus, it seems very promising to introduce into clinical practice the electrohysterography (EHG), as a method which enables noninvasive recording of readable bioelectrical signal of uterine muscle [1, 4]**.**

Contraction of the uterine muscle cell is a result of the flow of ion currents which causes in the cell surrounding a change of electromagnetic field called the bioelectrical activity. In the signal of potentials difference recorded between two points on maternal abdominal wall, the bioelectrical activity during uterine contractions is manifested by the bursts of action potentials. They occur synchronously with the mechanical uterine activity. Current knowledge concerning electrical uterine activity confirms that the complete information on this kind of activity can be obtained from the signal analyzed in the frequency band of 0 ÷ 5 Hz. However, the useful frequency bands are: 0.005 ÷ 0.03 – slow wave component representing occurrence of bursts, which occur synchronously with the mechanical uterine contractions, and 0.1 ÷ 3 Hz – fast wave component which is supposed to comprise information on electrophysiological properties of the uterine muscle. The EHG signal can be modelled as an action potentials fast wave whose amplitude is modulated by the slow wave corresponding to the contractions frequency. Such model allows us for a detection of the uterine contractions in the electrohysterogram and performing their time domain analysis in similar way as for conventional tocogram. The additional spectral parameters can be obtained exclusively from the analysis of the EHG fast wave. This feature of the electrohysterography makes it very promising approach for evaluation of the risk of premature labour on the early stage of pregnancy. In this paper we described an attempt to estimate the efficiency of a set of parameters obtained from the EHG signal analysis for evaluation of a risk of premature labour.

2. METHODOLOGY

2.1. SIGNAL ACQUISITION

The research system for simultaneous recording of mechanical and electrical uterine activity is presented in Fig. 1. The computerized system for fetal monitoring MONAKO [2] was used as the channel for measurement of the mechanical activity, whereas the electrical activity was acquired by means of the system for acquisition and analysis of bioelectric signals KOMPOREL [5]. The HP 1351 fetal monitor (Hewlett-Packard, USA) equipped with strain gauge transducer was used as an input device in the fetal monitoring system. The monitor is connected to the computer through the interface unit, which accepts different types of signal output connection including digital serial link and analog output. Additionally, the interface unit assures the patient's safety complying with general international standards for medical equipment. Incoming signals of mechanical uterine activity (UC) are on-line analyzed and stored in the system database.

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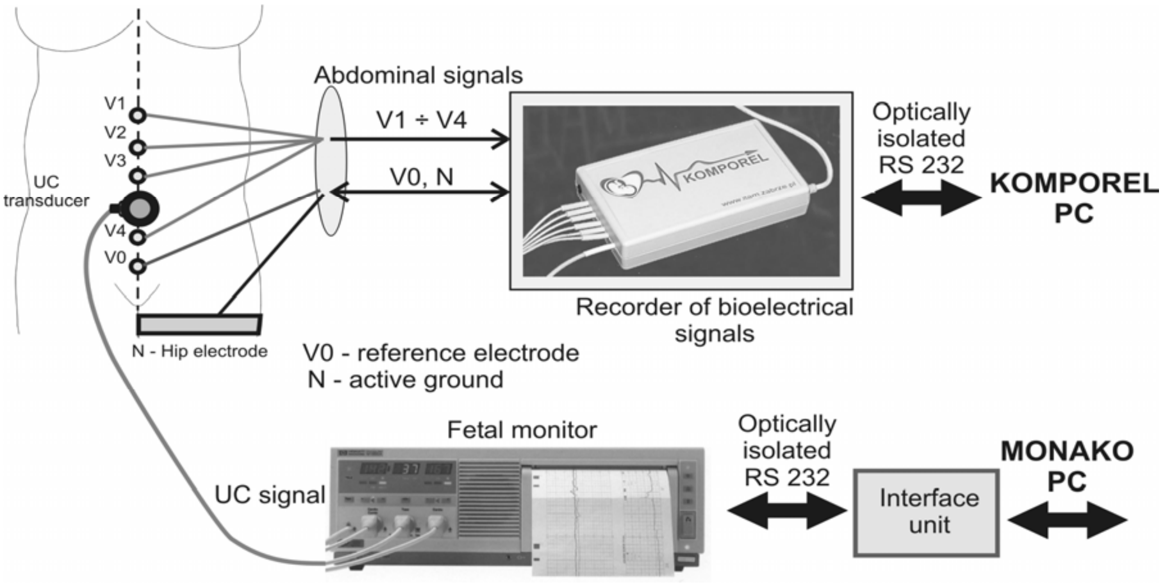

Fig.1. System for simultaneous recording of mechanical and electrical uterine activity.

The system for acquisition and analysis of bioelectric signals being recorded on maternal abdomen surface consists of two separate parts: the microcontroller-based recorder of bioelectric signals and external computer. Recording circuit in a form of external, optically isolated module enables both the fetal ECG signal acquisition and electrical uterine activity by using the same signals being recorded on maternal abdomen surface. Entire circuit allows the amplification of recorded signals from the tens of microvolts up to a few volts level. Gain adjustment prevents the reaching of saturation state by the amplifiers in case of strong isoline drift. Moreover, the band-pass filters allow the change of lower cut-off frequency from 0.05 Hz to 1 Hz, thus also securing the circuit against too large low-frequency interferences. Selection of proper gain and cut-off frequency of filters can be done using virtual instrumentation screen at the beginning of monitoring taking into account the visual assessment of abdominal signals recorded. High cut-off frequency of filters is established at 150 Hz, hence at the sampling frequency of 500 Hz, the recorder circuit is fully protected against a possibility of aliasing occurrence.

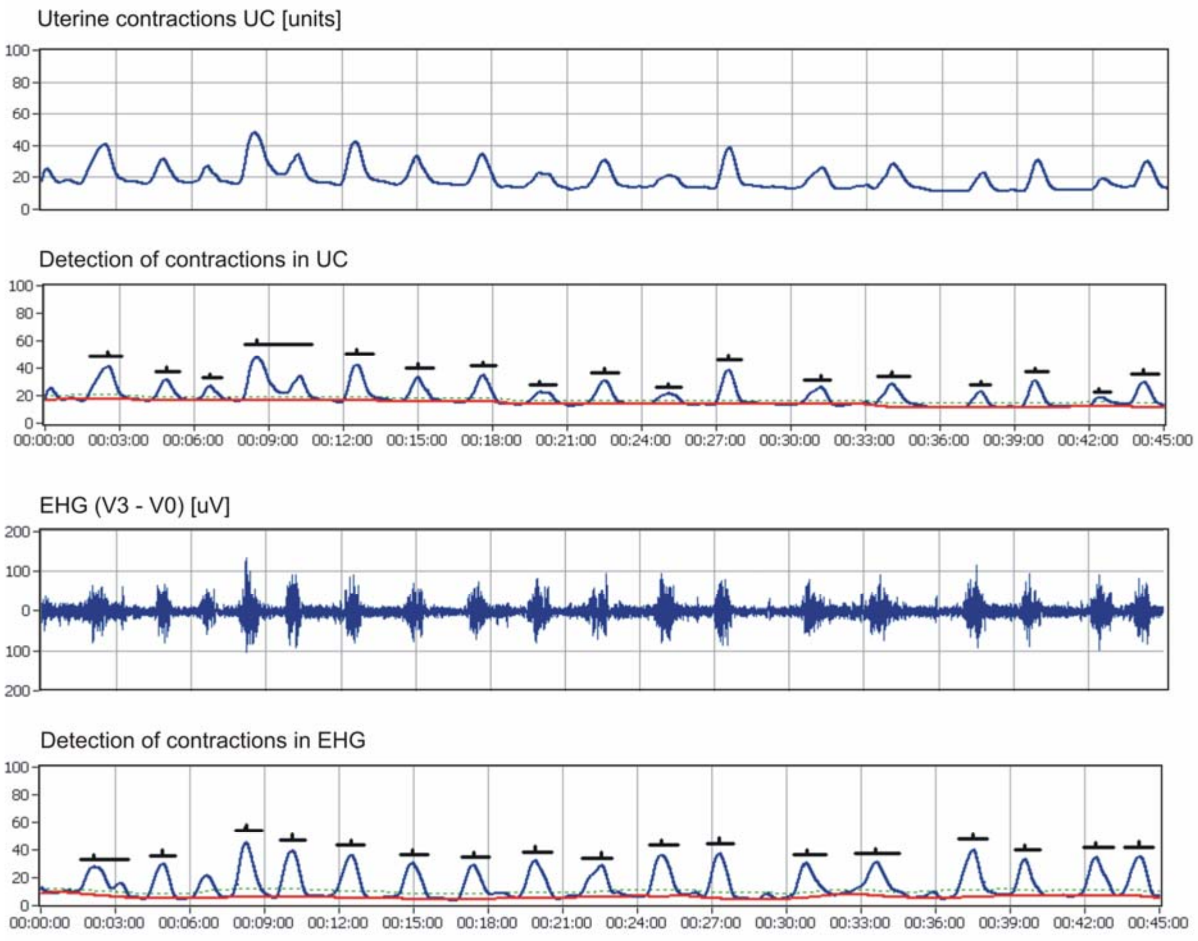

Fig.2. Uterine electrical activity signals acquired from abdominal leads (V3-V0),
together with simultaneously recorded mechanical activity.

Typical configuration of the abdominal electrodes comprises four electrodes placed around the navel and the reference electrode placed above the pubic symphysis. Additionally on the left leg, the common mode reference electrode is placed. Electrical activity of uterus is

presented in all leads, however the strongest differential signal is obtained usually in the channel which is formed by two electrodes placed in the vertical median axis of the abdomen.

2.2. MATERIAL

Duration of one monitoring session was between 10 and 60 minutes (43 minutes on average), which allowed us to recognized from 15 to 25 contractions in each trace (Fig.2). Material was divided into two groups: Group I with 27 patients in physiological pregnancy between 27 and 40 gestation week, and Group II comprising 21 patients between 23 and 36 week with the symptoms of premature threatening labour.

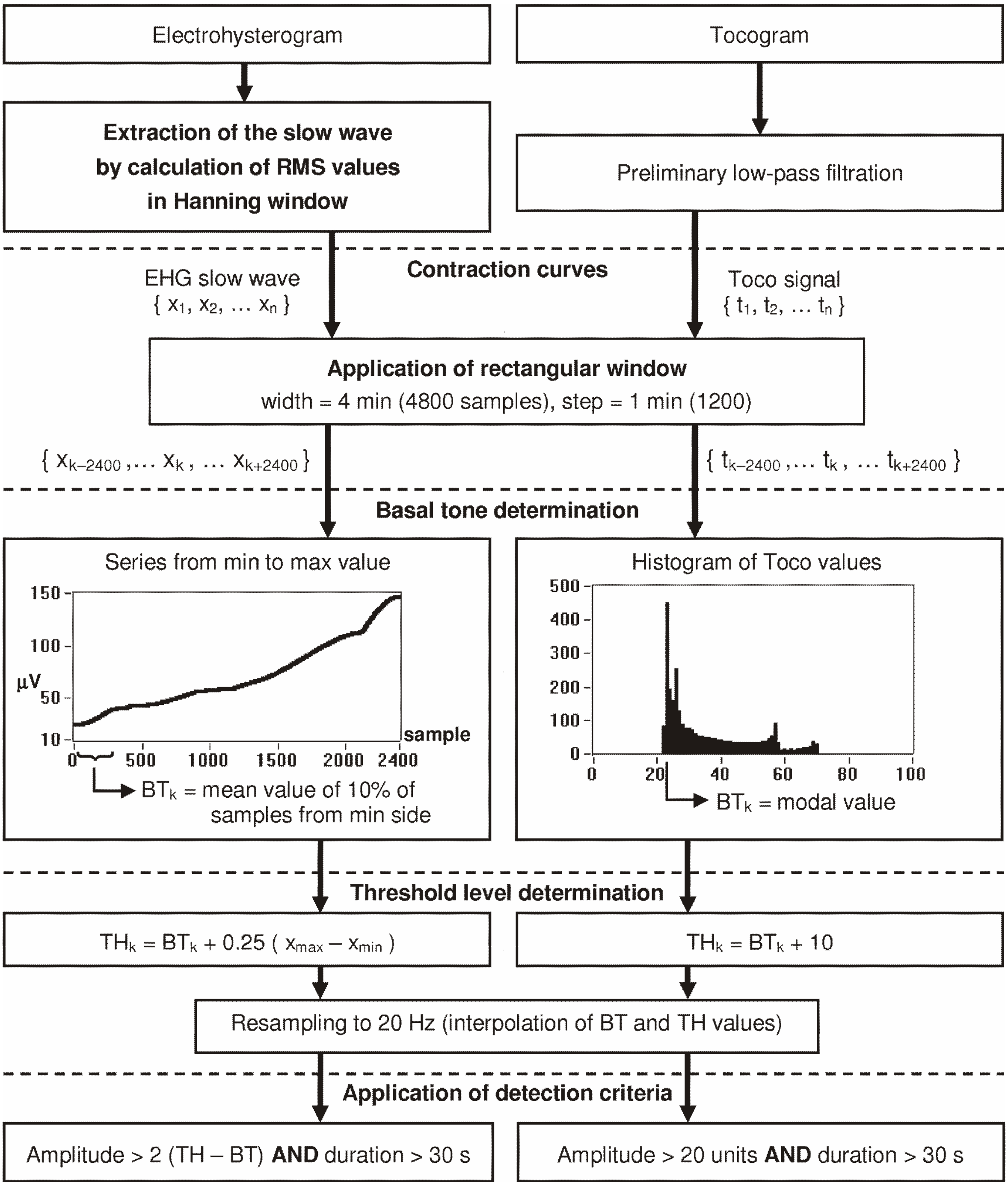

Fig.3. Overview of the algorithms for uterine contractions detection in the electrohysterogram and tocogram.

2.3. SIGNAL ANALYSIS

In the fetal monitoring system the on-line analysis of UC signal relies on determination of quantitative parameters describing the detected uterine contractions: occurrence rate R_{UC}, duration D_{UC}, amplitude A_{UC} and area S_{UC} pattern. Detection relies on finding those segments in the UC signal whose amplitude exceeds the threshold level by 20 units for period longer than 30 seconds. The threshold level is obtained by adding the constant value of 10 units to the so called basal tone (Fig. 3). The basal tone represents some resting strain exerted by the uterine muscle on the strain gauge transducer when contractions do not occur. The basal tone, which slowly changes during monitoring, is estimated basing on the analysis of UC values frequency distribution of the UC values [3].

In order to detect the contractions in electrohysterogram and to perform their classical time domain analysis, it is necessary first to extract the slow wave from acquired signal (Fig. 3). The method of extraction of slow wave corresponding to UC signal is based on calculation of consecutive root-mean-square values in 60 s window stepped with 3 s. Unlike the mechanical activity signal, the amplitude of electrohysterogram strongly depends on a given patient. Therefore, the algorithm applied for contractions detection should to compensate the amplitude variation between electrohysterograms [3]. Contractions detected from EHG are described by the following quantitative parameters: occurrence rate R_{EHG}, duration D_{EHG}, amplitude A_{EHG} and area S_{EHG}.

After calculation of pattern timing parameters the segments with bursts of action potentials are selected from the raw EHG signal. They are used to determine parameters exclusive for electrical uterine activity: signal power P, median frequency F_{med}, maximum power frequency F_{max} and contraction intensity I.

3. RESULTS

General descriptive statistics determined for quantitative parameters of contractions detected both in mechanical (UC) and electrical (slow wave component of EHG) signals is presented in Table 1. As it can be seen, statistically significant differences were obtained between corresponding parameters in each group. In the Group I (women in physiological pregnancy) such conclusion concerns occurrence rates (R_{EHG} and R_{UC}), durations (D_{EHG} and D_{UC}), and finally areas of detected contractions (S_{EHG} and S_{UC}). Whereas in the Group II (patients with symptoms of premature threatening labour) only occurrence rates (R_{EHG} and R_{UC}) show significant differences. The obtained results confirm different characteristics of mechanical and electrical uterine activity. Additionally, in each group the contraction occurrence rate is higher for electrical activity, which suggests that the electrohysterography is indeed more sensitive method for uterine contractions detection.

In the next stage the significances of differences concerning contraction parameters between investigated groups was estimated. When analyzing the results presented in Table 2 it can be noticed that there are so called common contraction parameters (possible to be obtained from both electrical and mechanical uterine activity) which differ the groups. For the EHG analysis, they are A EHG and S EHG while for the UC analysis only S UC (statistical significancy < 0.05).

Table 1. Descriptive statistics describing quantitative parameters of contractions in both groups.

Parameter	**Group I**				**Group II**			
	Mean ± SD	Min	Max	**p**	Mean ± SD	Min	Max	**p**
R EHG [1/10 min]	3.2 ± 0,6	2.4	4.4	*	3.4 ± 0.9	2.0	6.3	*
R UC [1/10 min]	1.9 ± 0.9	0.2	3.6		2.4 ± 1.2	0.5	5.1	
D EHG [s]	88.6 ± 17.6	61.4	122.4	*	85.1 ± 20.5	48.4	129.2	
D UC [s]	78.2 ± 34.0	38.0	211.3		84.6 ± 30.6	38.5	166.8	
A EHG [uV]	33.8 ± 53.6	3.8	285.4		62.2 ± 75.3	2.3	320.8	
A UC [-]	18.8 ± 13.8	3.7	63.7		31.7 ± 21.3	7.7	94.0	
S EHG	1815 ± 3011	186	16140	*	2841 ± 2809	200	10766	
S UC	1095 ± 1305	87	6675		1531 ± 1009	250	3813	

* means statistical significancy (p<0.05)

However the contraction amplitudes both from electrical and mechanical approaches are quite inaccurate measures, because they depend on the measurement conditions and a given patient. When applying the electrohysterography we can use exclusive parameters. Two of them: contraction power (P) and median frequency (Fmed) can be used to distinguish between groups of patients in physiological pregnancy and at risk of preterm threatening labour.

Table 2. Statistical significance of the particular parameters differentiating the investigated groups.

Parameter	Group I (Mean ± SD)	Group II (Mean ± SD)	I – II (p < 0.05)
UC			
R UC [1/10 min]	1.9 ± 0.1	2.4 ± 1.2	–
D UC [s]	78.2 ± 34.0	84.6 ± 30.6	–
A UC [-]	18.8 ± 13.8	31.7 ± 21.3	–
S UC	1095 ± 1305	1532 ± 1009	+
EHG			
R EHG [1/10 min]	3.2 ± 0.6	3.4 ± 1.0	–
D EHG [s]	88.6 ± 17.6	85.1 ± 20.5	–
A EHG [uV]	33.8 ± 53.6	62.2 ± 75.3	+
S EHG	1815 ± 3011	2841 ± 2809	+
I	17.5 ± 3.7	18.0 ± 4.5	–
P	1823 ± 5390	7492 ± 18098	+
F med [Hz]	0,30 ± 0.11	0.35 ± 0.10	+
F max [Hz]	0,25 ± 0.18	0.32 ± 0.29	–

\+ means statistical significancy (p<0.05)

4. CONCLUSIONS

Identification of these pregnant women who are at risk of premature threatening labour leads to an enhanced perinatal surveillance which should allow for efficient tocolitic treatment and stimulation of fetal lungs growth. Therefore, there is still a need for development of novel, more accurate and commonly accessible methods for monitoring early symptoms of the premature increase of the uterine activity. Since the electrohysterography provides complete information on functioning of uterine muscle it may fulfil these requirements and play a leading role in modern perinatology. Our study has shown that the noninvasive electrohysterography ensures higher sensitivity and specificity for recognition of uterine contraction activity in comparison to manual palpation and classical mechanical method.

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