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Early predicting a risk of preterm labour by analysis of antepartum electrohysterograhic signals

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ABSTRACT

This study is aimed at evaluation of the capability to indicate the preterm labour risk by analysing the features extracted from the signals of electrical uterine activity. Free access database was used with 300 signals acquired in two groups of pregnant women who delivered at term (262 cases) and preterm (38 cases). Signal features comprised classical time domain description, spectral parameters and nonlinear measures of contractile activity. Their mean values were calculated for all the contraction episodes detected in each record and their statistical significance for recognition of two groups of recordings was provided. Obtained results were related to the previous study where the same features were applied but they were determined for entire signals. Influence of electrodes location, band-pass filter settings and gestation week was investigated. The obtained results showed that a spectral parameter – the median frequency was the most promising indicator of the preterm labour risk.

1. Introduction

Preterm labour is a main cause of neonatal deaths. In addition, a premature infant usually needs to be hospitalized in neonatal intensive care unit which leads to an increase of the healthcare costs. Therefore, early recognition of the preterm labour symptoms is very important as it could enable an effective treatment and prolong a pregnancy period as close as possible to the predicted delivery term. It has been confirmed in clinical practice that the classical external tocography is not sufficient for precise classification of patients at risk of preterm labour, because this method measures only the mechanical result of the contractile activity [1,2]. Since each uterine contraction must be preceded by the electrical excitation which arises and then propagates through a uterine muscle, monitoring of the electrical uterine activity accomplished by electrohysterography (EHG) seems to be capable to solve this problem [3–5]. So far, most studies have been aimed mainly at application of EHG as the alternative approach to the tocography to provide information on uterine contractile activity during pregnancy and labour [6–8]. Such information is useful for classification of the fetal recordings in order to assess the fetal state [9–12]. Some studies concerned the action potential conduction velocity as the predictor of preterm labour [13,14].

The EHG signal can be modelled as an action potentials fast wave whose amplitude is modulated by a slow wave corresponding to the contractions rate [15,16]. Thus, when analysing the electrohysterogram, not only the time domain

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parameters used for classical description of mechanical contraction episodes, but also some additional parameters relating to action potential activity can be determined [17–19]. Estimation of their efficiency to differentiate between EHG signals recorded from pregnancy which ends at term and prematurely was the aim of our investigations.

2. Material and methods

Research material has been obtained through the Physionet.org platform, which gives free access to many databases of biophysical signals [20]. We used the database from [21] with the 300 EHG recordings grouped as follows:

A. *Term* group comprising 262 electrohysterograms from pregnancy ended with delivery during or after the 37th week of gestation, which is divided into two subgroups with:
I. 143 *early* recordings – acquired before the 26th week of gestation;
II. 119 *late* recordings – acquired during or after the 26th week.
B. *Preterm* group comprising 38 electrohysterograms from pregnancy ended prematurely i.e. before the 37th week, which is divided into the same two subgroups but with:
III. 19 *early* recordings;
IV. 19 *late* recordings.

It is worth to be noted that such impaired proportion of the numbers of recordings in preterm and term group is very common when considering the monitoring of pregnant women. In vast majority of cases a fetus develops properly and the pregnancy ends at term. It leads to very low number of abnormal cases in a typical perinatal database collected in a given hospital.

The signals were recorded by means of four electrodes placed on abdominal wall over the uterine muscle to form the square of seven centimetres side (Fig. 1). Three differential channels were formed: top horizontal ($S1 = E2 - E1$), right vertical pair ($S2 = E2 - E3$) and bottom horizontal ($S3 = E4 - E3$). Each signal underwent preprocessing which relied on band-pass filtering in three different frequency bands: $F1 = 0.08 \div 4$ Hz, $F2 = 0.3 \div 4$ Hz and $F3 = 0.3 \div 3$ Hz. According to the authors of this database, the first band enabled them to compare with other studies, while the narrower bands were aimed at removal of interferences coming from skin stretching or breathing as well as testing the susceptibility of the methods applied to EHG signals to frequency content in the higher frequencies. When acquiring electrical signals by electrodes attached to maternal abdomen, besides the uterine activity, the maternal and fetal electrocardiograms are also present in measurement channels [22,23].

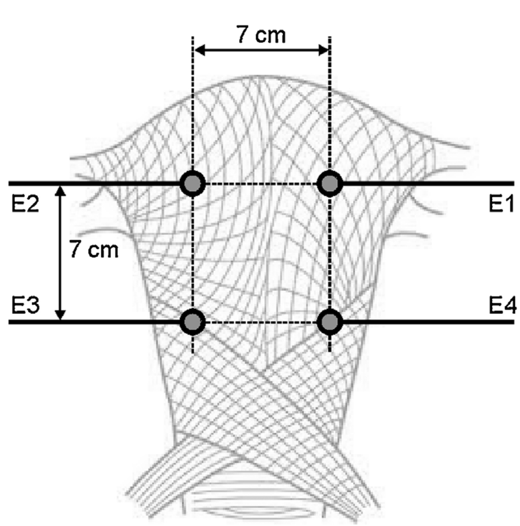

Fig. 1 – Electrodes placement on maternal abdomen used to record uterine electrical activity in three channels: $S1 = E2 - E1$, $S2 = E2 - E3$, $S3 = E4 - E3$.

Uterine contractile activity is reflected in the electrohysterogram by the bursts of action potential spikes, which occur synchronically with the intrauterine pressure increases [24,25], as well as with the contraction periods observed in the mechanical signal (Fig. 2) when being simultaneously recorded by a strain-gauge transducer attached to maternal abdomen [26–28]. Therefore, unlike in [21] where the whole EHG signals were processed, we proposed to calculate the EHG features only for the signal segments which showed the contractile electrical activity. It enabled to include the standard time-domain description of contractions into the features set. For recognition of the contractile segments in EHG signals we used the previously developed procedure, which detailed description can be found in [29]. This algorithm consists of the following steps: determination of the EHG slow wave which represents the strength of contractile activity, determination of the so called basal tone which corresponds to the resting potential, application of detection level above the basal tone to detect the candidate episodes of increased activity and finally their validation as contractions when duration T_D and amplitude A related to the basal tone exceeds the established minimal values T_{Dmin} and A_{min}, respectively (Fig. 3).

The database we have used in this study does not comprise any reference information, like simultaneously recorded mechanical activity or human experts' annotations, which could enable to verify the contractile activity segments detected. However, we formerly verified our algorithm by using the information on uterine contractions obtained from the tocography signals recorded simultaneously with electrohysterograms [7]. What's more, our algorithm was compared with few other proposed algorithms for detection of contractions in EHG signals. And when relating to reference intrauterine pressure measurements, our algorithm showed satisfying performance, although not so high as provided by the methods proposed in [24,25]. Though, the recordings in those studies were acquired just before or during delivery. It may be expected that the antenatal recordings included in our study may show a weaker uterine electrical activity. Therefore, we analysed the EHG signals for their ability to distinguish between the threatening preterm and term labour also separately in the groups of early and late recordings. Comparing the results obtained in both groups might in some way validate the algorithm when being applied for pregnancy recordings.

Duration, amplitude and the area under the EHG envelope constitute the classical description of contraction in time