Estimation of a sample entropy value useful for prediction of an upcoming labour based on an electrohysterographical signal

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Introduction

• A serious problem in reproductive epidemiology is still minimization of preterm labour occurrences.

• Monitoring of uterine mechanical contractions does not enable to predictive an upcoming labour.

• The complementary method is proposed which bases on monitoring of an uterine bioelectrical signal (called EHG) and its analysis using Sample Entropy Index.

• However, a cut off value of a Sample Entropy Index which differentiates physiological states of a pregnant uterus is still unknown.
Aims of the study

• The goal of the perform preliminary study was to estimate such value of a sample entropy index computed for EHG which enables to differentiate between an upcoming labor and a being labor.
The EHG measurements
Methods

- The idea supporting application of sample entropy to EHG analysis results from the observations that an electrical activity of an uterus becomes more regular when a labor is forthcoming.

An example of EHG signal during a labor and during a puerperium.
The sample entropy estimation

Let \( x(n) = [x_1 \ x_2 \ \cdots \ x_N] \) denotes \( N \)-elements time series representing EHG signal. Then, the estimation algorithm is consisted of the following steps:

(i) creating of \( m \) vectors defined as:
\[
X(i) = [x_i \ x_{i+1} \ \cdots \ x_{i+m-1}] \quad \text{for} \quad i = 1, \ldots, N - m + 1
\]

(ii) calculation of a distance between two vectors in the following way:
\[
d_m[X(i), X(j)] = \max_{k=0, \ldots, m-1} \left[ |x_{i+k} - x_{j+k}| \right]
\]

(iii) calculation of number of similar segments in two vectors:
\[
n_m = \#d_m[X(i), X(j)] \leq r, \text{ dla } i \neq j
\]
\[
n_{m+1} = \#d_{m+1}[X(i), X(j)] \leq r, \text{ dla } i \neq j
\]
where \( r \) is a tolerance parameter

(iv) calculation of similarity measures of these segments:
\[
B_i^m(r) = \frac{1}{N - m - 1}n_m \quad \text{dla } i = 1, \ldots, N - m
\]
\[
A_i^m(r) = \frac{1}{N - m - 1}n_{m+1}
\]

(v) calculation of mean measures of the similar signal segments:
\[
B^m = \frac{1}{N - m} \sum_{i=1}^{N-m} B_i^m(r)
\]
\[
A^m = \frac{1}{N - m} \sum_{i=1}^{N-m} A_i^m(r)
\]

(vi) calculation of Sample Entropy estimation
\[
\text{SamEn}(m, r) = - \ln \frac{A^m(r)}{B^m(r)}
\]
The GAM for cut-off estimation

- The GAM was used to estimate a cut-off of the sample entropy value which differentiates between an upcoming labour and a labour.

- The used generalized additive model is be expressed in the following form:

\[ P(L = 1 \mid \text{SamEn}) = \frac{\exp[\alpha + f(\text{SamEn})]}{1 + \exp[\alpha + f(\text{SamEn})]}, \]

where:

- \( L \) is a binary variable. \( L=1 \) denotes a labour occurrence.
- \( f \) is an unknown smooth function estimated based on sample entropy values.
Clinical observations

- EHG signal was registered in 49 women being in third trimester of their pregnancies without any clinical symptoms of an upcoming labour and in 31 women during a labour.
The relation between the values of sample entropy and an odds ratio for a labor.

For SamEn < 0.6 a labour risk increases.
Conclusions

• The obtained results suggest that there is a nonlinear relation between the regularity of EHG signal measured by Sample Entropy Index and an odds ratio of a labour.

• It seems that values lower than 0.6 may predict an upcoming labour.

• An identification of factors which can affect this relation such as a patient’s obesity, location of an uterus and a gestational age requires further investigations.