From EHG signals to graphs: A new method for predicting premature birth.

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Abstract — The objective of this paper is to present the framework of an advanced approach aiming at characterizing the electrohysterographic (EHG) signals recorded during pregnancy and labor. The approach is based on the analysis of the propagation of the uterine electrical activity. The processing include i) the estimation of the statistical independences between the recorded EHG signals, ii) the characterization of the obtained connectivity matrices using network measures (graph-theory based analysis) and iii) the use of these measures in clinical application: the classification of signals recorded during pregnancy and labor. However, a number of methodological questions are still open regarding the optimal way to process the data in order to achieve the clinical application. In this abstract we tackle one of these issues related to the connectivity methods to be used in order to produce the connectivity matrices. We evaluate more than one method using a physiological uterine EMG model developed recently in our team.

Index terms - EHG, connectivity methods, connectivity matrix, graph theory, prediction of premature birth

I. INTRODUCTION

Numerous studies have shown that the analysis of the propagation of the uterine electrical activity is a very powerful tool to characterize the uterine bursts and to discriminate between pregnancy and labor in order to the early prediction of the preterm labor [1]. This propagation was investigated by evaluating the statistical dependences (denoted as uterine connectivity) between electro-hysterographic (EHG) signals recorded from 16 channels arranged on the abdomen of pregnant women. Several methods and techniques have been applied such as the use of nonlinear correlation coefficient (h^2) [1], the phase synchronization or the use of segmentation algorithm to improve the connectivity results [2]. In almost all previous studies, the correlation matrix was always reduced keeping only its mean and standard deviation. Although the results obtained were encouraging, we assume that important information was missing. If we consider each electrode as a node, and define the edges as the connectivity value between signals, we can use the graph theory to characterize the correlation matrix and quantify the associated connectivity graph. This is the main originality of the proposed work.
However, a number of questions are still open regarding the optimal way to process the data. One of these questions is the choice of the connectivity methods. This question is addressed here by evaluating five connectivity methods on physiological EHG model.

II. METHODS AND RESULTS

Overview:
The aim of our approach is the classification of labor and pregnancy EHG signals using the networks measures. The complete pipeline is shown in Figure 1. The first step consists in recording the EHG signals. A pretreatment step (figure 1a) is performed in order to remove the artifacts contaminating the raw signals (see [3] for details about the denoising algorithm developed by our team). The second step is to compute the connectivity between the denoised signals (figure 1b). The obtained connectivity matrix is then transformed to a graph where several measures can be extracted (based on graph theory). These measures will be used for, firstly characterizing the uterine contractions at different terms (along pregnancy and during labor, figure 1e) and then, to evaluate the clinical power of the approach by computing the classification rates of the computed network measures in classifying between pregnancy and labor contractions (figure 1d).

Evaluation of connectivity methods.
One of the many methodological questions of the pipeline described in figure 1 concerns the connectivity method to be used in our application. To proceed, we first evaluate four methods that are widely used in studying connectivity between electrophysiological signals. The chosen methods are: nonlinear regression (h^2), granger causality (GC), general synchronization (H) and mean phase coherence (MPC).

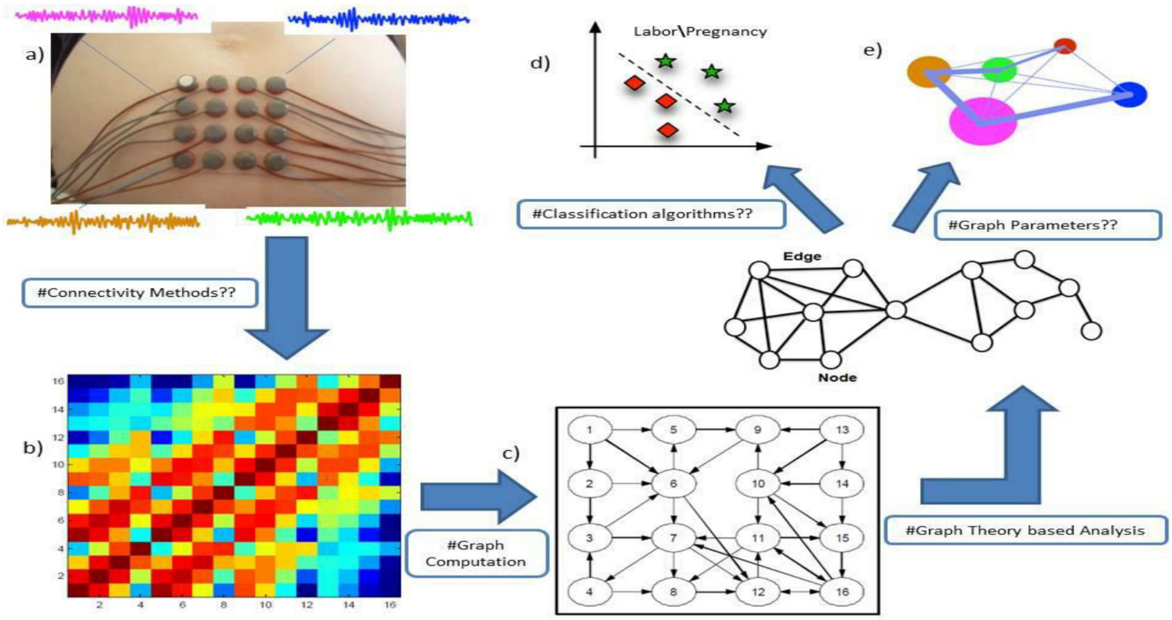

Figure 1 : Structure of the investigation. (a) EHG signals recorded using a grid of 4*4 electrodes. (b) Connectivity matrix. (c) Simple graph where each electrode is a node and the edges are the value of correlation between signals. (d) Classification labor\pregnancy using graph algorithms. (e) Extraction of graph parameters

To get free of the effect of the conducting volume, we then added the imaginary coherence (ICoh) which is supposed to reduce this effect. The chosen methods are then evaluated by using a model developed in our team [4]. The model was used to generate signals with different coupling values (represented by the temporal delay- varying from 0 to 1- between the generated uterine sources). The five connectivity methods were then applied to simulated signals at each coupling value. The preliminary results of the evaluation of the connectivity methods on the model are presented figure 2.

All the tested methods present some evolution when coupling value is smaller than 0.7, and reach their maximum value, when coupling is near to 1. By estimating the standard deviation, only the imaginary coherence (Icoh) presents some Non monotoneous evolution. Furthermore, the general synchronization (H) presents the highest values (its value increases from 0.45 to 1). On the other hand, h^2 presents a monotoneous evolution when coupling is greater than 0.3.

III. DISCUSSIONS AND CONCLUSION

In this paper, we have presented the complete framework of a new approach aiming at characterizing the propagation of the uterine electrical activity. We evaluate the methodological question that appears in the whole processing which is the choice of the connectivity methods. We evaluate five methods (h^2, Icoh, H, GC, and MPC) on realistic EHG model. Results showed some variability between the tested methods with high performance for h^2, H and ICoh.

These methods will be then used to generate the connectivity graphs where network measures will be extracted. This is the main objective of our further work. We speculate that this new approach using the graph measures will have a high impact in the usefulness of the EHG signal in clinical application: the detection of labor and the prediction of preterm labor.

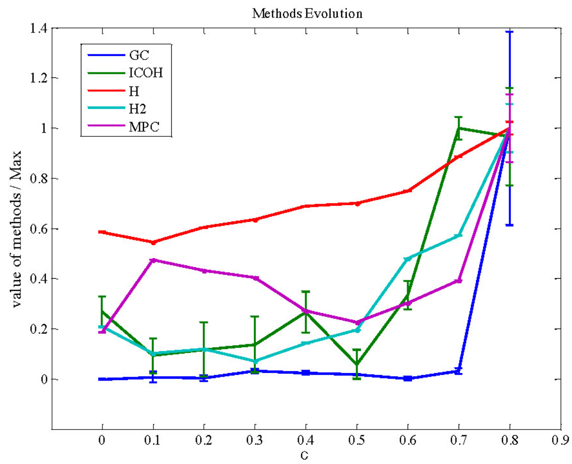

Figure 2: Evolution of connectivity methods in function of coupling degree.

REFERENCES

[1] M. M. Hassan, J. Terrien, C. Muszynski, A. Alexandersson, C. Marque, and B. Karlsson, “Better Pregnancy Monitoring Using Nonlinear Correlation Analysis of External Uterine Electromyography,” *IEEE Trans. Biomed. Eng.*, vol. 60, no. 4, pp. 1160–1166, Apr. 2013.

[2] J. Terrien, M. Hassan, C. Marque, and B. Karlsson, “Use of piecewise stationary segmentation as a pre-treatment for synchronization measures,” in *30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2008. EMBS 2008*, 2008, pp. 2661–2664.

[3] M. Hassan, S. Boudaoud, J. Terrien, B. Karlsson, and C. Marque, “Combination of Canonical Correlation Analysis and Empirical Mode Decomposition Applied to Denoising the Labor Electrohysterogram,” *IEEE Trans. Biomed. Eng.*, vol. 58, no. 9, pp. 2441–2447, Sep. 2011.

[4] J. Laforet, C. Rabotti, J. Terrien, M. Mischi, and C. Marque, “Toward a Multiscale Model of the Uterine Electrical Activity,” *IEEE Trans. Biomed. Eng.*, vol. 58, no. 12, pp. 3487–3490, Dec. 2011.