

Analysis of Echographic and Heart Rate Time and Frequency Domain Parameters for the Antepartum Fetal Surveillance

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Abstract

The paper describes a preliminary analysis of fetal heart rate parameters and echographic measurements performed in a population of about 60 fetuses including Normal and Intra Uterine Growth Restricted cases. The objective is to improve the early detection of fetal suffering conditions by measuring a multiparametric set including time and frequency domain parameters, complexity indexes and biometric measure. This analysis constitutes the first step of a wider project whose final target is to realize a prototype clinical decision support system devoted to the early identification of fetal well being modifications. The results herein presented show that the echographic indexes can help discriminating between the two groups but they may be a late sign of a distressed state of fetus.

1. Introduction

In the monitoring of fetal conditions, what we are looking for is always a reassuring indication that the fetus (which is only observable in an indirect way) is in a wellbeing state.

A correct and early (27th-35th week) identification of fetal distress and of the associated risk is a central issue in obstetrics as it drives the decision of inducing premature delivery [1].

Several clinical trials, based on a comparison with neonatal diagnosis, have shown a high percentage of false positives in terms of antepartum incorrect diagnosis of intra uterine growth restriction (IUGR). This represents a relevant problem in the clinical management of the pregnancy, as IUGR condition is often associated to high probability of iatrogenic diseases in the premature newborn.

This outcome contrasts with the increasing diffusion of non-invasive monitoring techniques such as cardiotocography (CTG) and echographic (ECHO) imaging and fluximetry.

Cardiotocography (CTG) allows comparing fetal heart rate (FHR) and uterine contractions ("toco") by means of

a echo-Doppler probe and a pressure sensor.

Echography instead provides precise morphometric measurements of the fetus (dimensions, malformations), behavioral information (movements), and, by Doppler shift, pulsatility indexes in the umbilical artery and in the ductus venosus.

The present work presents a preliminary analysis of distress condition in IUGR fetuses obtained by CTG signals and echographic parameters which have been measured in a synchronous way. It constitutes the first step of a wider project.

All the research efforts in this field are mainly dedicated to reach this fundamental objective: improving the health of the fetus thus preventing disease events. High quality standards of medical surveillance during pregnancy are supposed to decrease life-threatening events, to decrease the number of fetal deaths and to prevent or at least to better manage disease conditions as the Intra Uterine Growth Restriction (IUGR), the most frequent fetal pathology.

The final target of the project is to realize a prototype clinical decision support system toward the early identification of fetal well being modifications.

2. Methods

The present work is a part of research project aiming at the development of a prototype clinical decision support system and at the improvement of the current decision scores for the early evaluation of fetal distress conditions. The project workflow is illustrated in Figure 1. The objective is pursued mainly by three ways:

1) Improving the information extraction from the CTG signals by computing frequency domain indices (low, movement related and high frequency spectral components from nonparametric spectral analysis), entropic indices (approximate entropy, ApEn, and sample entropy, SampEn) [2][3]. In addition, advanced complexity indexes (multiscale entropy [4], Lempel Ziv complexity [5], cross-entropy [3] and mutual information [6]) are also included.

2) Integrating CTG analysis with Echographic data and

pulsatility indexes (ductus venosus and umbilical artery) [7].

3) Developing a prototype hybrid system, including multi-layer perceptron, adaptive neuro-fuzzy system, support vector machine classifiers, genetic algorithms and a case-based reasoning module.

2.1. Parameter description

The considered database includes 66 CTG and Echo recordings: 30 belonging to Normal and 36 to IUGR fetuses. The gestational age ranges from 29th to 39th weeks.

The Table 1 summarizes the parameter set adopted for the preliminary analysis on FHR signals. The table shows also the application characteristics and the physiological meaning.

Morphological parameters are variability indexes as Short Term Variability (STV), Long Term Irregularity (LTI), Delta, Interval Index (II) and number of accelerations and decelerations [8][9].

Frequency domain parameters from spectral analysis accomplish the index set. Low, Movement and High Frequency powers as well as their ratio quantify the activity of the control mechanisms regulating the heart frequency as a function of the fetal development. Approximate Entropy measures the regularity of FHR.

The echographic exam allows evaluating biometric data and fetal morphology as well as to study the vascular response in different organs and to extract pulsatility indices predicting fetal sufferance [7][10].

Echographic parameters are composed by biometric measures such as Biparietal Diameter (BPD), Head Circumference (HC), Abdominal Diameter (average) and Circumference (AC), femur length (FL). Blood velocity in the Umbilical Artery (UA) and in the Medium Cerebral Artery (MCA) as well as their ratio UA/MCA are obtained by echo Doppler techniques.

The measurement of the arterial flow, e.g. in cerebral and cerebellar arteries, which is obtained through the color Doppler instrumentation, allows analyzing vascular resistances and monitoring the mechanisms that the hypoxic and distressed fetus activates [11].

3. Results

Small differences are noticeable in the time and frequency domain parameters but the reduced number of cases limits their ability in separating the two considered groups. Echographic parameters measuring the blood velocity are sensitive to the IUGR condition. In particular the UA/MCA shows higher values in IUGR than in Normal fetuses (P-value<0.001, T-test). Furthermore, the

lowest values of the Apgar Score (a number associated to the newborn wellbeing at delivery), which have been obtained in IUGR fetuses group, are related to UA/MCA>1 which is considered clinically abnormal.

The use of Doppler ultrasound in high risk pregnancies appears to be promising in reducing perinatal deaths. Fetuses with abnormal Doppler velocimetry had a significantly higher incidence of oligohydramnios, low birth weight and admission to neonatal ICU. Umbilical velocimetry however is a test of placental function that does not always directly reflect fetal status.

Biometric measures clearly separate Normal from IUGR suffering fetuses, but they cannot distinguish real IUGR from small for gestational age fetuses (SGA).

Pulsatility indexes seem to be the most reliable indicators of fetal distress, but they might be a "late" sign and the fetus could be in an irreversible pathological condition.

Advances in Doppler ultrasonography have improved access to the fetal circulation. There has been a great deal of interest in the fetal intracranial vessels. Knowledge of Doppler flow velocimetry of the fetal MCA may assist in perinatal diagnosis and management of complicated pregnancies. A low index of resistance in the middle cerebral artery associated with fetal compromise has been described [10].

4. Discussion and conclusions

This preliminary analysis suggests that a multiparametric approach through the integration of both FHR advanced analysis techniques and echographic measures can improve the diagnostic ability of the fetal monitoring systems.

In IUGR fetuses, the biometric measures evidence the poor development in terms of smaller dimension, but they can only be a confirmation of a pathological condition

Doppler velocimetry studies of placental and fetal circulation provide important information regarding fetal distress, although an increase of their values might be too late for recovering a fetal damage.

FHR regularity parameters could represent a further step towards a reliable and early detection of fetal distress. The integration of the multiparametric approach should be done through advanced classification techniques able to discriminate distressed fetuses in nonlinear regions of a multidimensional space. Although the sample size of our study was small, our results suggest that the analysis based on a multiparametric set could produce a good predictive tool for neonatal outcome in complicated pregnancies and could be also used to identify fetuses at risk of morbidity.

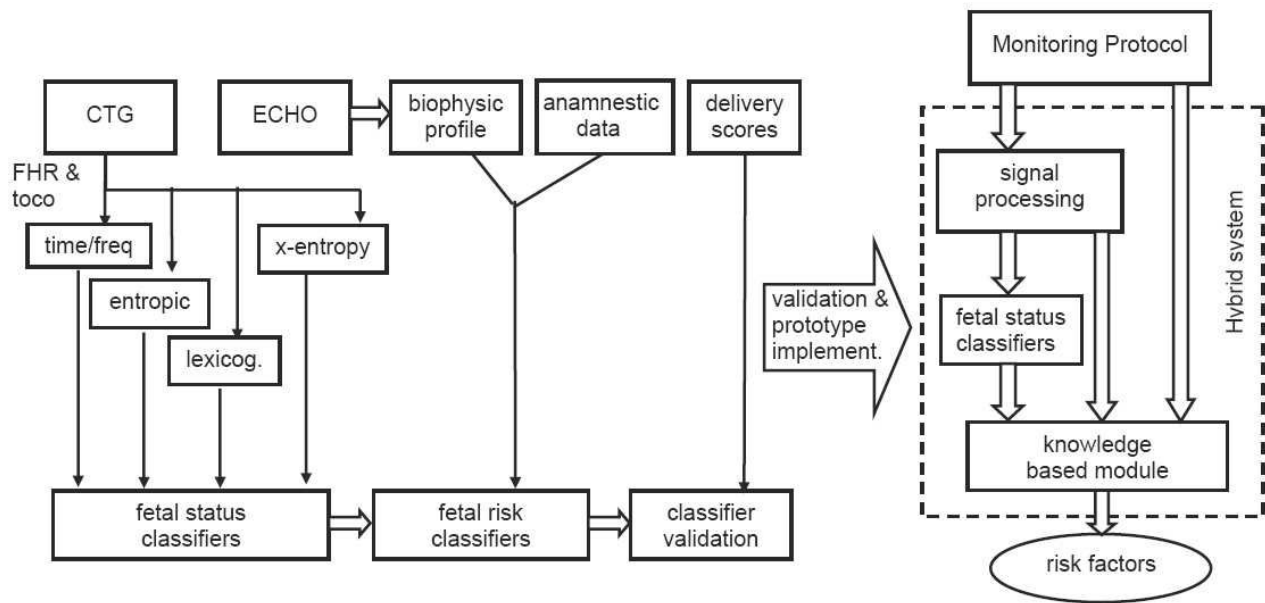


Figure 1: Data flow for the project of the advance monitoring and classification system prototype for the early evaluation of fetal distress conditions.

Table 1: The time and frequency domain parameter set

METHOD	PARAMETERS	TIME SERIES LENGTH	HYPOTHESES
Frequency Analysis	% value of power in		
	LF 0.03-0.15Hz	3 min	Quantification of control activity by the nervous system
	MF 0.15-0.5Hz	360 samples	
HF 0.5-1Hz			
Time domain methods	Delta (msec)	1 min	Short period variations
	STV (msec)	120 samples	
	II		
	Average FHR (msec)	3 min	Long period variations
	LTI (msec)	360 samples	
Morphology	N. of accelerations (small and large)	1 hour	Events of fetal reactivity
Approximate Entropy	ApEn(1,0.2)	3 min 360 samples	Presence of recurrent patterns at a single scale

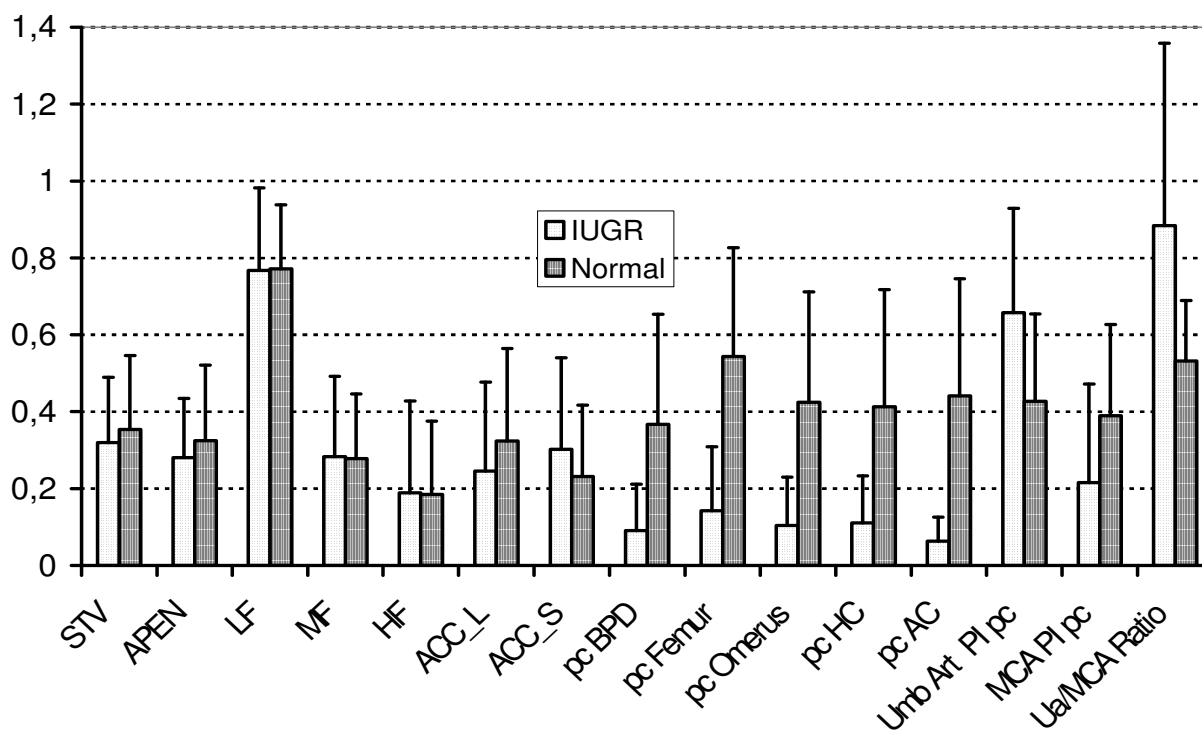


Figure 2: Results obtained in Normal and IUGR fetuses by calculating time and frequency domain parameters, regularity indexes, echographic indexes.

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