Abstract

The most important method for fetal monitoring is recording and monitoring of fetal heart rate (FHR) and analysis of fetal heart rate variability (fHRV). fHRV analysis have a physiological significance because changes in FHR are coupled to fetal well-being. The fetal heart rate (FHR) and its beat-to-beat variability are important parameters in the observation of the fetal condition. The importance of this subject has been felt as every year about one out of 125 babies are born with some form of congenital heart defects. Congenital heart defects originate in early stages of pregnancy when the heart is forming and they can affect any of the parts or functions of the heart.

The medical reports shows about 12.8 percent of babies are born prematurely due to their nervous system growth problems. This problem can be detected during gestation period if we measure the heart rate of the fetus during his growth. Fetal heart starts pulsating at around 250 BPM at 12 weeks of gestation period and it decreases down to around 120 to 150 BPM at ninth month. The average heart rate & heart rate variation are related to development of the fetal nervous system and development of different body organs’ are related to autonomic nervous system. Our studies include design and development of fetal heart rate variation measuring system & use the fetal heart rate data to define the diagnostic indices for fetal growth monitoring. These diagnostic indices can be utilized to predict the fetal future life complications and can be utilized for preventive measure. Our design system not only measures heart rate variation but also heart rate power spectrum which can be utilized for determining diagnostics indices helpful for the medical community.

Heart rate variability of fetal and neonatal is an important area of investigation, and it provides early information about fetal and neonatal distress and identifies those at risk for sudden infant death syndrome. Heart rate variability (HRV) analysis provides a quantitative marker of the autonomic nervous system (ANS) as the regulation mechanisms of HRV originate from the sympathetic and parasympathetic nervous systems. HRV signal can be used as a signature of state of heart. Insight into autonomic maturation in the developing fetus might be possible through proper applications of more sophisticated power spectral techniques.

In our study we present a novel efficient technique for processing of the Doppler ultrasound signal which could estimate the cardiac cycle duration with accuracy comparable to direct electrocardiography. The direct electrocardiography as a reference technique up till now ensures
the highest possible accuracy of heart interval measurement. The proposed method has been
developed to calculate beat-to-beat basis power spectral information of the fetal heart rate (FHR)
in stages of pregnancy earlier than labor from Doppler ultrasound signal. The developed real time
Doppler ultrasound fetal data acquisition technique and real time direct fetal electrocardiogram
(FECG) monitor has been tested in a local hospital on a sample group of 64 pregnant women at
different intervals during gestation period. The results revealed that Doppler ultrasound method
enables to calculate reliable parameters describing the variability of FHR compared to the direct
fetal electrocardiogram. This reliable Doppler ultrasound system detects all fetal heart beats
reducing the number of invalid cardiac cycle measurements considering limitation of measuring
system parameters in five minutes recording of each subject. The processing of acquired signals
was implemented using LABVIEW environment virtual instrumentation software system.
National Instruments ELVIS II+ with USB plug-and-play capabilities was utilized for data
acquisition and display of FHR signal from Doppler ultrasound system for quantification of heart
rate variability.

We have studied and discussed method of an estimation of fetus condition includes abdominal
beat-to-beat fetal heart rate (FHR) signal registration with Doppler ultrasound monitoring,
correlation processing of the received data, fetal R-R intervals allocations, estimation of
distribution parameters and diagnostic index calculation, describing activity of sympathetic and
parasympathetic nervous systems of fetus. The different linear and nonlinear parameters
evaluated show a particular range for identification of autonomic maturation in the developing
fetus. It is also observed that the HRV parameters are less random as gestation age increases for
normal fetus.

The system is design to measure the fetal heart rate variability for the evaluation of
autonomic nervous system (ANS) indices in the normal and abnormal fetus. We studied 64
maternal abdominal Doppler ultrasound signals. From these, we identify 41 subjects of
pregnancies whose body mass index (BMI) is ranging from 20 to 37. The method consists of
three steps: Doppler envelope filter, variable threshold detector and non retriggerable
monostable multivibrator having adjustable pulse width for heartbeats detection. We defined a
coefficient of variance (CVRR) as an index of parasympathetic activity which is defined as ratio
of standard deviation of normal RR intervals value to mean of such intervals, and defined a low
frequency/high frequency (LF/HF) ratio as a sympathetic activity. Analysis based on the time-
domain, frequency domain and nonlinear analysis of heart rate variability enable an evaluation of fetal autonomic nervous system (ANS) activity. It is also observed that the parasympathetic nervous activity increased with gestational age in the normal pregnancy group.

We tested the hypothesis that maternal body mass index (BMI) determines fetal cardiac sympathetic activity. Heart rate variability (HRV) parameters of fetus are measured for obese and non-obese mother prior to delivery with Doppler ultrasound method. The value of LF/HF ratio [Nonparametric Fast Fourier Transform (FFT) Based method] in normal pregnancy group displayed clearly decreasing trend with increase in body mass index (BMI). The value of LF/HF ratio [Parametric Autoregressive (AR) Based] in normal pregnancy group displayed clearly decreasing trend with increase in body mass index (BMI). In consultation with gynecologists and child specialist it has been verified that the new born babies have more neurological problems following deliveries from obese mothers compared with deliveries from non-obese mothers.

We have tested the hypothesis that a LF/HF ratio [Nonparametric Fast Fourier Transform (FFT) Based] as an index of fetal sympathetic activity is a function of ten variables, age, gestation week, body mass index, CVRR %, HR Mean, HR Std, RMSSD, NN50, pNN 50 and non linear index SD1/SD2 ratio, a multiple regression analysis was performed. The overall model explained 36.12 percent of the variation in LF/HF ratio as an index of fetal sympathetic activity can be explained by ten independent variables. We can also see that age, CVRR %, HR mean, HR Std, and RMSSD are significant predictors (or significantly related to) of LF/HF ratio [Nonparametric Fast Fourier Transform (FFT) Based] as an index of fetal sympathetic activity. Gestation week, Body mass index, pNN50 and SD1/SD2 index is not a significant predictor of LF/HF ratio [Nonparametric Fast Fourier Transform (FFT) Based] as an index of fetal sympathetic activity. The standardized beta tells us the strength and direction of the relationships (interpreted like correlation coefficients). CVRR % is positively related to LF/HF ratio [Nonparametric Fast Fourier Transform (FFT) Based] as an index of fetal sympathetic activity.

We have tested the hypothesis that a LF/HF ratio [Parametric(AR) Based] as an index of fetal sympathetic activity is a function of ten variables, age, gestation week, body mass index, CVRR %, HR Mean, HR Std, RMSSD, NN50, pNN 50 and non linear index SD1/SD2 ratio, a multiple regression analysis was performed. The overall model explained 46.47 percent of the
variation in LF/HF ratio as an index of fetal sympathetic activity can be explained by ten independent variables. We can also see that age, CVRR %, HR Std, and RMSSD are significant predictors (or significantly related to) of LF/HF ratio [Parametric (AR) Based] as an index of fetal sympathetic activity. Gestation week, Body mass index, HR Mean, NN50, pNN50 and SD1/SD2 index is not a significant predictor of LF/HF ratio [Parametric (AR) Based] as an index of fetal sympathetic activity. The standardized beta tells us the strength and direction of the relationships (interpreted like correlation coefficients). CVRR % is positively related to LF/HF ratio [Parametric (AR) Based] as an index of fetal sympathetic activity.

**Key words:** obesity, autonomic nervous system, Doppler ultrasound, heart rate variability, fetal heart rate