Heart Rate Variability using Poincaré Plots in 10 year old Healthy and Intrauterine Growth Restricted Children with Reference to Maternal Smoking Habits during Pregnancy

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Abstract

This paper is looking at the effect of maternal smoking on 10 year intrauterine growth restricted compared to normal children. Lomb periodogram and Poincaré plots were used for this assessment.

It is found that during waking, the LF/HF ratio showed IUGR children whose mothers did or did not smoke during pregnancy have elevated levels (2.66, 2.89) respectively, compared to the normal groups (2.23, 2.18). During sleep, the LF/HF ratio was (0.69, 0.79) for IUGR children, and (0.52, 0.52) for normal children.

The Poincaré analysis of long-term variability suggested that IUGR children whose mothers smoked during pregnancy have less long term HRV during sleep (SD2=148.53ms) than their healthy counterparts whose mothers smoked (SD2=182.87ms), p=0.02, and significantly lower short-term variability value was found for IUGR asthmatic children whose mothers smoked.

1. Introduction

Heart diseases are one of the major causes of mortality in the western world, and heart rate variability is a very useful tool for identification of cardiovascular risk in humans [1], a reduced HRV is always correlated to increased risk of cardiovascular mortality in adults[4]. Intrauterine growth restricted (IUGR) term describes a slower rate of fetal growth which prevents the fetus from having a complete normal growth [2]. Intrauterine growth children are those who have their biometric dimensions below the 10th percentile. In this paper Lomb periodogram was used to find the power spectral density (PSD), because lomb method, as shown by Moody [3], estimates the PSD directly from irregularly sampled time series. The standard methods of finding PSD Fourier transform and autoregressive approaches require resampling of the time series data to get uniform RR intervals, and this can introduce a low pass effect to the PSD estimates. The LF and HF were calculated from PSD, so comparison between the IUGR and normal children can be done. Another method used to look at the effect of maternal smoking habit on cardiac function at 10yrs children was the Poincaré plots(see figure 1). It is known as return maps or scatter plots where the current RR is plotted against the following RR. A graphical presentation of RR can be produced with SD1 as the short term variability and SD2 as the long term variability. The SD1/SD2 represents the randomness in HRV time series, and this ratio has the strongest association with mortality in Adults [4]. The specific aim of this work is to use Lomb method and Poincaré plots to study and analyse the effect of maternal smoking habit on the development of the autonomic nervous system of normal and IUGR children.

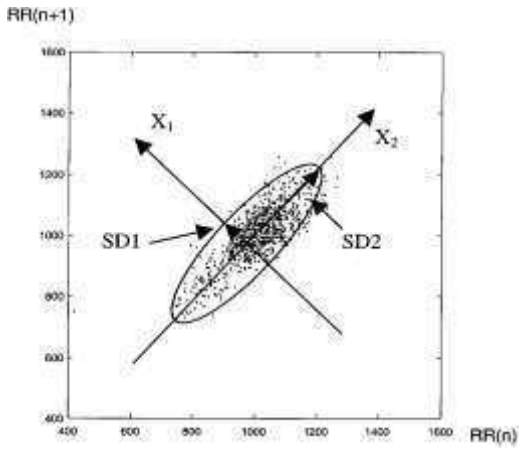

Figure 1. Example of Poincaré plot showing the orientation of the axes and SD1/SD2 values

2. Data

A 24-hour ECG at 10 years old for each child was taken, starting at approximately at 3 PM. This was provided with parentally noted number of sleep hours. The ECGs of the study population were analysed according to parental smoking status and birth weight of the child (IUGR or not).

The 73 children were initially sorted into 4 groups, depending on IUGR, Normal and their maternal smoking habit during pregnancy. Table 1 shows the breakdown of the population into these subsections.

Table 1. Grouping of children with respect to maternal smoking

Birth weight of child	Maternal smoking during pregnancy	Number of children	Child Numbers
IUGR	Smoker	13	33-45
IUGR	Non-Smoker	24	46-69
Normal	Smoker	8	1-8
Normal	Non-Smoker	24	9-32

The emphasis of this paper is the study of the development of IUGR children subjected to passive smoking during pregnancy.

3. Method

3.1. Frequency domain analysis

Lomb periodograms were used in order to show the power of the spectra, and then to evaluate the LF/HF ratio for all the children during awake and asleep. The Lomb method evaluates sine waves at times (t_i), which are actually measured. This way there is no need to interpolate values onto a grid before using FFT methods.

The Lomb normalized periodogram (spectral power as a function of angular frequency, $\omega \equiv 2\pi f > 0$) is given by:

$$P_N(\omega) \frac{1}{2\sigma^2}\left\{\frac{[\sum_j (h_j-\bar{h})\cos\omega(t_j-\tau)]^2}{\sum_j \cos^2\omega(t_j-\tau)} + \frac{[\sum_j (h_j-\bar{h})\sin\omega(t_j-\tau)]^2}{\sum_j \sin^2\omega(t_j-\tau)}\right\}$$

(Equation 1)

The mean, $\bar{h}$ of the data by:

$$\bar{h} \equiv \frac{1}{N}\sum_1^N h_i \qquad \text{(Equation 2)}$$

And the variance of the data, σ^2 by:

$$\sigma^2 \equiv \frac{1}{N-1}\sum_1^N (h_i-\bar{h})^2 \qquad \text{(Equation 3)}$$

$P_N(\omega)$ is completely independent of shifting all the t_i's by a constant τ, which is defined by the following relation:

$$\tan(2\omega\tau) = \frac{\sum_j \sin 2\omega t_j}{\sum_j \cos 2\omega t_j} \qquad \text{(Equation 4)}$$

Lomb method provides a more accurate result than that of the FFT as it 'weighs data on a "per point" basis instead of on a "per time interval" basis' [5] thus ruling out any error created as a result of uneven sampling.

3.2. Non-linear method-Poincaré plot

The feasibility of using a software package to allow HRV analysis was studied and as a result, the 'kubios HRV, version 2.0' software was implemented [6]. The software for Poincaré analysis uses ellipse fitting, for calculation of SD1 and SD2 values. Figure 1 shows a typical poincarè plot with the ellipse fitting and the values of SD1 for short term variability and SD2 for long term variability. The averages of SD1 and SD2 for all children have been tabulated as shown in table 2.

Table 2. Average of SD1, SD2 and SD1/SD2 for all children

Group	Mean SD1	Mean SD2	Mean SD1/SD2
Normal Smoking	70.61	182.87	0.37
Normal Non-smoking	69.04	166.07	0.41
IUGR Smoking	60.33	148.53	0.40
IUGR Non-smoking	69.20	161.64	0.40

4. Results

Lomb Periodograms were produced for all of the children in this work. The lower PSD is marked in blue and

the highest is in red. The Respiratory Sinus Arrhythmia (RSA) is shown in the periodogram in red at frequency of respiration of 0.25 Hertz.

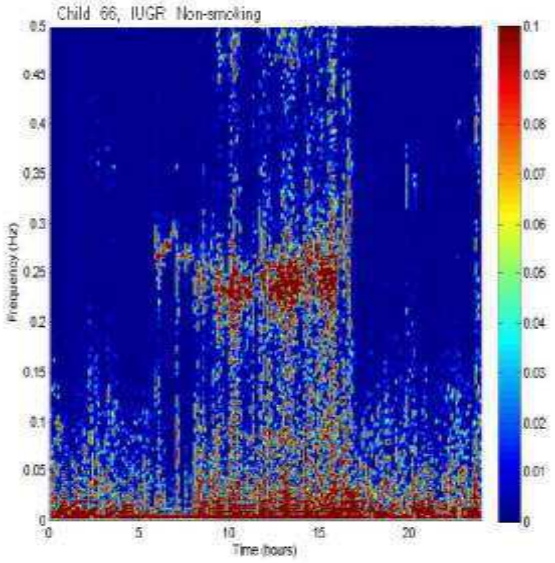

Figure 2. The Lomb periodogram for an IUGR child with a non-smoking mother during pregnancy, the red colour at 0.25 Hz shows the respiratory sinus arrhythmia (RSA) at night time.

A summary of the LF/HF values and the standard deviation for the groups during awake and sleep are shown below in Table 3.

Table 3. The LF/HF for all 4 groups during awake and sleep

Group	LF/HF (awake)	LF/HF (sleep)
Normal Smoking	2.234±1.227	0.524±0.304
Normal Non-smoking	2.189±1.258	0.529±0.359
IUGR Smoking	2.667±1.23	0.697±0.498
IUGR Non-smoking	2.897±2.611	0.799±0.872

The implementation of Kubios software, allowed us to select the sleep time and to draw Poincarè plots for all the children and consequently to evaluate SD1 and SD2 for all normal and IUGR children, with smoking and non-smoking maternal habit. Figure 3 shows Poincarè plots for two normal, and two IUGR children with different maternal smoking habits during pregnancy.

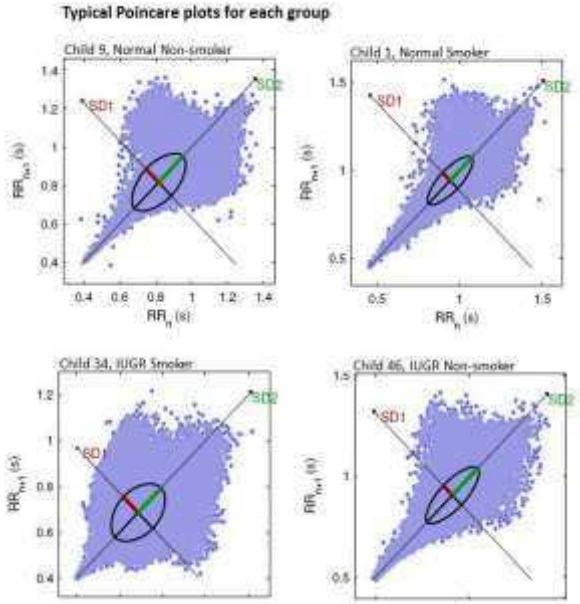

Figure 3. Four typical Poincarè plots

5. Statistics

A t-test was used to compare between the LF/HF of all four groups with respect to maternal smoking habit during pregnancy. Table 4 shows the p value when comparing array 1 with array 2 using t-test.

Table 4. The result of a t-test when comparing the LF/HF, with p values for sleep and awake period

Array 1	Array 2	LF/HF P value sleep	LF/HF P value awake
Normal Smoking	Normal non-smoking	0.976	0.930
Normal Smoking	IUGR smoking	0.389	0.445
Normal Smoking	IUGR non-smoking	0.394	0.497
Normal Non-smoking	IUGR smoking	0.243	0.275
Normal Non-smoking	IUGR non-smoking	0.167	0.238
IUGR Smoking	IUGR non-smoking	0.702	0.767

The p values in table 4 shows no significant differences between the groups in array 1 and array 2 during awake and asleep when using t-test to compare between the LF/HF ratios of all four groups.

From the SD1 and SD2 data for all children a t-test was done to find the p value between all the groups, table 5 shows the results of the t-test and p values.

Table 5. The p values for SD1 and SD2 between array 1 and array 2

Array 1	Array 2	Poincaré SD1 T-test	Poincaré SD2 T-test
Normal Smoking	Normal non-smoking	0.900	0.249
Normal Smoking	IUGR smoking	0.428	0.020
Normal Smoking	IUGR non-smoking	0.931	0.236
Normal non-smoking	IUGR smoking	0.332	0.149
Normal non-smoking	IUGR non-smoking	0.987	0.714
IUGR Smoking	IUGR non-smoking	0.461	0.366

The only p value less than 0.05 is when comparing between normal smoking and IUGR smoking groups for SD2, which means that there is a significant difference between the two groups. There were 9 asthmatic children in the study: 4 IUGR smoking, 2 IUGR non-smoking, 2 normal non-smoking and 1 normal smoking. The mean Poincaré SD1 value for the asthmatics that were IUGR smokers was 53.4 ms, the lowest SD1 value of all the groups and it is significantly lower than that of the IUGR smokers (60.34 ms). The low asthmatic IUGR smokers SD1 value indicates a decrease in short-term variability of the heart whilst the IUGR child is sleeping.

6. Discussion and conclusion

During waking, the LF/HF ratio showed that IUGR children whose mothers did or did not smoke during pregnancy have elevated levels (2.66, 2.89) respectively, compared to the normal groups (2.23, 2.18). During sleep, the LF/HF ratio was (0.69, 0.79) for IUGR children, and (0.52, 0.52) for normal children. The Poincaré analysis of long-term variability suggested that IUGR children whose mothers smoked during pregnancy have less long term HRV during sleep (SD2=148.53ms) than their healthy counterparts whose mothers smoked (SD2=182.87ms), and p=0.02. Poincaré testing suggested that asthmatic children were consistently returning different results compared to the other children in their groupings. Following this, a Poincaré analysis was employed from which significantly lower short-term variability value was found for IUGR asthmatic children whose mothers smoked.

It is suggested that smoking during pregnancy can have adverse implications for the development of the autonomic nervous system of the IUGR child. The children with respiratory problems (asthma) showed a decrease in short-term variability amongst the IUGR smoking group. This may be caused by the Salbutamol medication. Salbutamol is a bronchodilator, meaning it relaxes airways to encourage greater air intake, thus changing the breathing rate.

Acknowledgements

This work is supported by a Grant from the Libyan Ministry of Higher Education and research, and it is part of the research portfolio supported by the Leicester NIHR Biomedical Research Unit in Cardiovascular Disease.

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