RESPIRATORY SINUS ARRHYTHMIA IN 10 YEAR OLDS
Normal and Intrauterine Growth Restricted

Taher Biala[1], Fernando Schlindwein[1], Michael Wailoo[2] and Michael Bankart[2]
[1] *Department of Engineering, University of Leicester, U.K.*
[2] *Department of Health Science, University of Leicester, U.K.*

Keywords: Respiratory sinus arrhythmia, Frequency domain analysis, Autoregressive model, Hypertension, Barker theory.

Abstract: Frequency domain analysis of RR has been determined by three methods, autoregressive model (AR), Fast Fourier Transform (FFT) and Lomb periodogram for 10 min segments. The first two methods were done after resampling and the third method without resampling RR series of all 75 children. AR was used in this work, and RSA was identified at night time during sleep. The area of the RSA was calculated for every 10 min interval and compared to the overall area of the 10 min segment, then the average RSA of all segments was calculated, as well as the overall percentage of the RSA energy to the total area for the whole period of sleeping. This was done firstly for a sample of Normal and IUGR 10 year olds. Secondly for all the children under study, an independent t-test concluded that there is no significant difference between the IUGR and Normal (p=0.7467).

1 INTRODUCTION

HRV is a powerful non-invasive tool used by physicians to determine the state of the heart and assess the development of the ANS. This work describes the results obtained by HRV analysis of two groups of children, 41 IUGR and 34 controls for a period of 24 h .The main objective of the work is to find any correlation between HRV of children at 10 years and the Barker Theory and hypothesis, which states that IUGR children are prone to coronary disease and hypertension in their adulthood (Barker, 2004). The RR interval normally oscillates periodically, shortening with inspiration and lengthening with expiration. This is known as Respiratory sinus arrhythmia, and it's due partly to the Bainbridge reflex via the expansion and contraction of the lungs and the cardiac filling volume caused by variations of intrathoracic pressure (Azuaje et al., 2007). During inspiration, the pressure within the thorax decreases increasing blood influx into the right atrium resulting in a reflex that increases the heart rate (i.e., shortens the RR intervals). During expiration, the reverse of this process results in a slowing of the heart rate.

2 METHODS

The Task force (Task force of European Society of Cardiology and the North American, 1996) specifies the standards used in HRV studies, where time domain and frequency domain analysis can be used to study heart rate variability.

The RR signal is subjected to a process of interpolation to obtain an equally spaced data to be used for spectral analysis. FFT and AR must have an equally spaced data to perform spectral analysis. The signal has been re-sampled at 4 Hz after a cubic spline data interpolation. This will give us the results in Hertz and allows the spectrum analysis up to 2 Hz. The AR spectral method (equation 1),(because of better resolution than FFT when dealing with low sampling Frequency), have been tested on the RR data to find the frequency components of the power spectrum for 10 min segments .The RSA frequency range (HF) is defined to be from 0.15 to 0.40 Hz (Azuaje et al., 2007).

Biala T., Schlindwein F., Wailoo M. and Bankart M. (2009).
RESPIRATORY SINUS ARRHYTHMIA IN 10 YEAR OLDS - Normal and Intrauterine Growth Restricted
.
In *Proceedings of the International Conference on Bio-inspired Systems and Signal Processing*, pages 510-513

2.1 Figures and Tables

The AR spectral analysis of 10 segments produces a graph as shown in Fig. 1. Graphs (a, b) are for Normal children, and (c, d), for IUGR children.

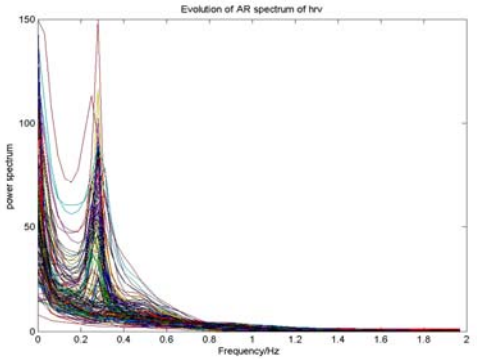

Figure 1(a): AR spectrum of Normal child with RSA.

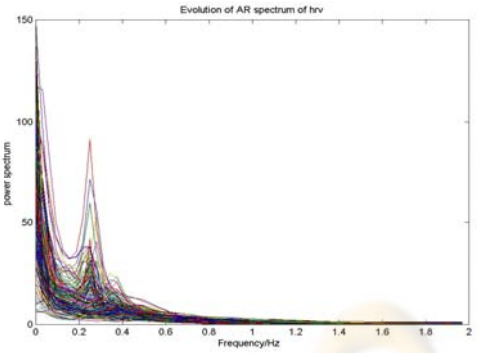

Figure 1(b): AR spectrum of Normal child with less RSA.

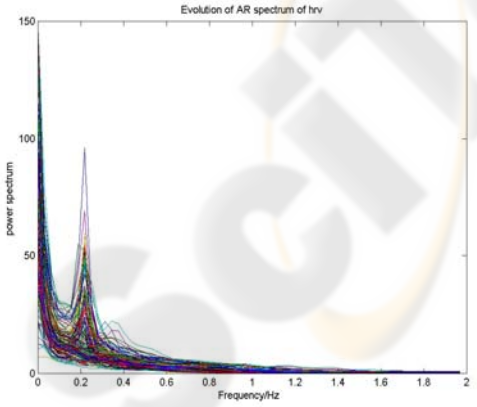

Figure 1(c): AR power spectrum of IUGR child with RSA.

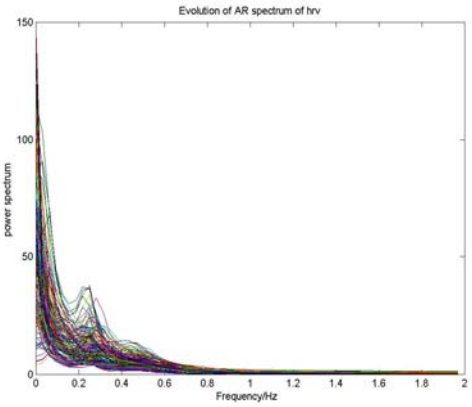

Figure 1(d): AR power spectrum of IUGR child with less RSA.

The application of an algorithm to find the energy of the RSA (area), by using Trapezoidal method (equation 2), produced the following table 1:

Table 1: The RSA Energy, Total, and % of RSA to Total for IUGR and Normal children.

No	child	RSA (energy) u^2	Total (energy) u^2	% RSA/ Total
1	IUGR	4.5936	10.3187	45.6287
2	IUGR	2.3244	5.8750	39.8064
3	IUGR	2.5484	5.5834	45.9105
4	IUGR	5.2631	10.6212	50.0502
5	IUGR	8.5370	18.5431	46.6481
6	Normal	6.9783	12.6834	54.7855
7	Normal	2.6899	6.7861	41.3924
8	Normal	3.6029	9.0093	40.0707
9	Normal	5.0364	11.0507	45.2321
10	Normal	3.7838	8.8850	43.0941

2.2 Equations

The equation of AR process of order p can be written as:

$$x_t = n_t + a_1 x_{t-1} + a_2 x_{t-2} + \ldots + a_p x_{t-p}$$

where n_t is the white noise driving signal p is the order of the AR model, and (a_1.....a_p) are the parameters of the filter.

The AR power spectrum density estimate is given by the following equation (Boardman et al., 2002):

$$P_{AR}(f) = \frac{\sigma^2 \Delta t}{\left| 1 + \sum_{K=1}^{p} a_K e^{-j 2\pi f k \Delta t} \right|^2} \quad (1)$$

Where σ^2 is the variance of the white noise driving function and Δt is the re-sampling interval.

The Trapezoid method in equation (2) was used to find the energy (area) of the RSA:

$$A = \frac{(a+b)h}{2} \quad (2)$$

Where (a and b) are the two parallel sides and h is the distance (height) between them.

Statistically, an independent t-test was used for equality of means between IUGR and Normal in terms of RSA, and to verify the Null hypothesis which is, there is no difference in the RT score (Average of all ratio of RSA energy to total energy within 10 min segment for night time).

Table 2 and 3 shows the results of the independent t-test:

Table 2: IUGR and Normal Independent t-test results.

Group	n	Mean	SD
IUGR	37	46.83	6.10
Normal	30	47.27	4.65

The t-test showed that there was no significant difference between the two groups for RT score, difference = 0.44, t = 0.32, p=0.7467 (95% CI = -3.1, 2.3). There was homogeneity of variance (Levene's Test, p=0.14) and the data was approximately normally distributed within each group.

Other variables were assessed for significance but none of them significantly predicted (RT) score, although IMD (Index of Multiple Deprivation) was borderline (0.06).

Table 3.

Variable	p-value
Sex *	0.32
Breast Feeding (y/n) *	0.50
Parental Smoking (y/n) *	0.99
Household Smoking (y/n) *	0.72
IMD #	0.06
24 hour SBP #	0.59
24 hour DBP #	0.87
BMI #	0.77
Significant Medication *	0.26
Using Medication *	0.36
Birth Weight #	0.45
Length Gestation #	0.50
Weight change from birth #	0.77
Night SBP #	0.79
Night DBP #	0.60
Day SBP #	0.46
Day DBP #	0.64
Cortisol morning #	0.29
Cortisol night-time #	0.66

* = independent t-test, # = correlation

3 DISCUSSION

The results obtained are both qualitative and quantitative. The graphs in Figures 1(a) and 1(b), show the evolution of the AR spectrum of the HRV for a Normal child. It can be seen that the RSA energy in child (a) is higher than the RSA energy for Normal child shown in Figure 1(b). The frequency at which RSA occurs in (a) is at 0.3 Hz, but for child (b), RSA occurs at 0.25 Hz. The RSA for IUGR children can be seen in figures 1(c) and 1(d). Child (d), has RSA at Frequency of 0.2 Hz, and Child (c), at approximately 0.25Hz. The calculations of RSA energy from IUGR and Normal children are shown in table 1 in arbitrary units squared (gain is not calibrated). The data presented in the table shows that the lowest energy of RSA is 39.8 u^2, and the highest is 50 u^2 for IUGR. Normal children has the lowest energy of RSA is 40 u^2, and the highest is 54.78 u^2.

The result of the t-test shows no significant difference between the two groups for the RT score, but when looking at other variables, IMD was found to be(p=0.06). Which means that the children who have high index of multiple deprivation (IMD) are very correlated with RT score, and consequently this

means that the deprived children don't have a synchronized breathing pattern at night time.

4 CONCLUSIONS

This work identifies the RSA in two ways, the first is graphically, and the second, in terms of the RSA Energy (area). RSA is an interesting phenomenon which represents the parasympathetic branch of the Autonomic nervous system. RSA occurs at frequency between 0.15 Hz and 0.4 Hz at night time and at this frequency (HF), RR intervals tend to be longer than at day time due to the parasympathetic tone, and consequently heart rate will be slower. At night ventilation is more regular; hence it is easier to identify the peak corresponding to RSA.

RSA can not be used to distinguish between the IUGR and normal children, because there is no significant difference between the two groups. Other variables, such as parental smoking and household smoking can not predict any differences in RSA.

Children who have high index of multiple deprivation (IMD) are very correlated with RT score, and consequently this means that the deprived children don't have a synchronized breathing pattern at night time.

REFERENCES

Barker DJP, "The development origin of chronic adult disease." Acta Paediaatrica., volume 93, pp, 26-33 (2004).

Azuaje F., Clifford D.G., MacSharry P., "Advanced Method and tools for ECG Data Analysis", (2007).

Task force of European Society of Cardiology and the North American, "Heart Rate variability-Standards of measurements, physiological interpretation, and clinical use", circulation, volume 93, pp. 1043-1065, (1996).

Boardman A., Leite A., Rocha A., Schlindwein F., "A study on the optimum order of autoregressive models for heart rate variability" Physiological Measurement volume 23, N.2, pp. 235-336, (2002).