PREGNANCY WOMEN'S STRESS USING NONLINEAR POWER SPECTRAL ANALYSIS

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ABSTRACT

The aim of the present study was to examine whether the parameters of cardiac R-R intervals reflect changes in the physical stress during delivery. Thirty patients took part in the study. Patient's cardiac R-R intervals were continuously registered in the period of sixty minutes before delivery and sixty minutes after delivery. The power spectral components HF, LF and LF/HF were used as the components of HRV in the analysis. The ratios of LF/HF were higher before delivery and lesser after delivery. Almost all HF component features measuring heart rate complexity were significantly decreased in the stress session. The results of the current study suggest that nonlinear HRV analysis using ECG recording could be effective in automatically detecting real-life stress condition, such as pregnancy women.

Keywords: Heart Rate (HR), Stress, Frequency domain, Power spectrum analysis
AMS classification: 00A69, 70K

1. Introduction

From our own experience, we will know that our heart starts beating faster, for example when we are running to the train station. On the other hand, it pumps less frequently when we are sleeping. This is basically what the idea behind heart rate variability (HRV) is; it is the term to describe the changing heart rate **[7]**.

During stress and exercise, the body requires a higher amount of oxygen. Consequently, the amount of blood which is pumped through the body has to be increased. The heart does so not only by beating faster, but also more strongly. In discussions about the control of the heart, heart rate variability is therefore often associated with an additional term, namely cardiac output. Cardiac output is defined as "the product of stroke volume (the volume of blood leaving the left ventricle with each beat) and heart rate (number of heart beats per minute)." A change in either the heart rate or the stroke volume or both affects the cardiac output. Usually, both factors interplay in order to adapt the body to a particular situation.

Our increased heartbeat will return to its normal level shortly after sitting in the train following the sprint. From this point of view, our heart can be compared to the movement of a simple pendulum, oscillating in a regular pattern. After it has been perturbed, it will soon settle back to its original pulse **[3].**

This traditional principle is known as physiological homeostasis: "Physiological systems normally operate to reduce variability and to maintain a constancy of internal function." So if the variation of heart rate was only due to the body‟s transient response to a fluctuating extrinsic environment, it would be periodic like a clock pulse otherwise. This is also the reason why clinicians often call the heartbeat normal sinus rhythm. But how regular is it really?

More careful analysis of the RR-intervals reveals that the normal heart rate of young and healthy people behaves most erratically, even at rest and in steady state conditions. The heart rate fluctuates considerably and can change as much as 20 bpm within a few beats. Therefore heart rate variability cannot only be explained in terms of cardiovascular homeostasis together with external perturbing influences. The fluctuations that lead to the irregular and unpredictable changes of the heart rate must also arise intrinsically **[4] [1].**

Counter- intuitively, heart rate variability is an important feature of health. It allows spontaneous beat-to-beat variations which are kept within an optimal range. Furthermore, decreased variability and increasingly regular behaviour are associated with disease and aging (Fig.1) **[5]**.

Considering the complex control systems of the heart it is reasonable to assume that nonlinear mechanisms are involved in the genesis of HRV. The nonlinear properties of HRV have been analyzed using measures such as Power Spectral Analysis, Detrended fluctuation analysis, Poincare plot, Approximate entropy and Sample entropy, Correlation dimension, and Recurrence plots. During the last years, the numbers of studies utilizing such methods have increased substantially. But in this work we have to discuss Power Spectral Analysis, however, the difficulty of physiological interpretation of the results.

1.1 Heart rate dynamics in Health and Disease

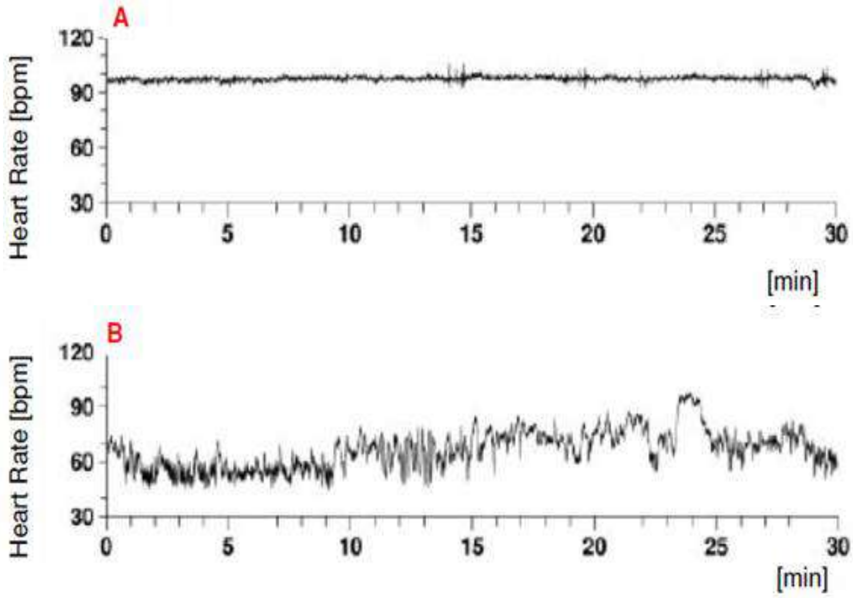


Figure 1: Heart rate variability (HRV) in health and disease: Note the irregularity and "Roughness" of the healthy heart rate time series (B). In (A), the patient suffers from severe heart failure. It can be clearly seen that his HRV is much reduced [2].

In healthy individuals heart rate is neither constant nor periodic. Instead, the variability in heart rate fluctuations is determined by the complex dynamics of the sympathetic and parasympathetic branches of the autonomic nervous system (ANS), which inter-act at the impulse generating tissue located in the right atrium of the heart (sinoatrial mode). Generally, sympathetic stimulation increases heart rate, while parasympathetic stimulation decreases it.

Heart rate variability is a composite of numerous influences reflecting physiological regulatory mechanisms. In the recent past there has been a spurt of research efforts involving HRV, based on the conviction that disentangling the sources of variation in cardiac dynamics will provide valuable information on the cardiovascular autonomic regulation of the heart.

1.2 Factors that can affect Heart Rate Variability

There are many internal and external factors that can affect HRV. For years some scientists have believed that there is a link between your psychological thoughts and your physical body and health. This is now being proven with HRV analysis.

Stress, both physical and psychological, can negatively affect your HRV measurements. If you are feeling „under the weather, less than perfect or a bit rough,‟ no matter what the reason, the chances are that your HRV will be negatively affected. Research has shown that individuals HRV can also be negatively affected by certain foods, alcohol, smoking, drugs (both prescribed and elicit) and all manner of products, some of which are supposed to promote health.

At times we all experience stress of one kind or another. In most cases people just get on with their lives hoping that things will improve or work themselves out. If this stress (whatever it may be) is short lived, then the body‟s natural ability to heal itself will resolve most problems and there will be no dramatic changes in HRV.

If the stress is long term, then there is an increased risk of physical and emotional fatigue which will be observed with HRV analysis. As an example, stress and fear, be it real or perceived, is experienced by an increase in heart rate. Left unchecked a person can adapt to this dysfunctional pattern and fatigue (mentally and physically) and emotional distress can occur. Consequently, hormonal and neurological overwork occurs and causes a decrease in life satisfaction and individual performance. Long term exposure to these processes can cause illness and disease such as cardiovascular disease, adult onset diabetes, anxiety, depression, panic disorders and so forth.

2. Stress

Your body tries to adjust to different circumstances or continually changing environment around you. In this process, the body is put to extra work resulting in "wear and tear". In other words, your body is stressed. Stress disturbs the body‟s normal way of functioning.

Most of us experience stress at one time or another. Without stress, there would be no life. However, excessive or prolonged stress can be harmful. Stress is unique and personal. A situation may be stressful for someone but the same situation may be challenging for others. For example, arranging a world level symposium may be challenging for one person but stressful to another. Some persons have habit of worrying unnecessarily.

People often work well under certain stress leading to increased productivity. Many times you do not know in advance and the stress periods may be sudden. The situation may not be under your control. Too much stress is harmful. You should know your level of stress that allows you to perform optimally in your life.

2.1. When we are stressed the following happens:

- Blood pressure rises
- Breathing becomes more rapid
- Digestive system slows down
- Heart rate (pulse) rises
- Immune system goes down
- Muscles become tense
- We do not sleep (heightened state of alertness)

2.2 Stresses in Pregnancy

Stress is a word that can be used to describe the way we feel, or it can be used to describe something that happens to someone. Many different things are included in the term stress:

Figure 2 Stress during pregnancy

Feelings of stress, anxiety or depression are very common during pregnancy. They may come and go, or they may persist. In around 15% of pregnant women, these symptoms are quite serious and could affect the development of the fetus. Although it is important to remember that it only increases the risk of problems and most children of even much stressed mothers are fine.

Most pregnant women who are experiencing emotional problems during pregnancy do not get any help from their doctor, nurse or midwife. It is very important that the pregnant woman is aware of how they feels, and asks for help when needed.

Although stress is known to affect fetal development, it certainly doesn't affect every fetus. Some mothers can feel quite stressed, without this having any effect at all.

3. Frequency domain

In this chapter, we have to discuss about Power Spectrum with respect to Frequency domain method. Frequency domain is a term used to describe the domain for analysis of mathematical functions or signals with respect to frequency, rather than time.

In general, a time-domain graph shows how a signal changes over time, whereas a frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. A frequency-domain representation can also include information on the phase shift that must be applied to each sinusoid in order to be able to recombine the frequency components to recover the original time signal.

A given function or signal can be converted between the time and frequency domains with a pair of mathematical operators called a transform. An example is the Fourier transform, which decomposes a function into the sum of a (potentially infinite) number of sine wave frequency components. The 'spectrum' of frequency components is the frequency domain representation of the signal. The inverse Fourier transform converts the frequency domain function back to a time function.

A spectrum analyzer is the tool commonly used to visualize real-world signals in the frequency domain.

3.1. Power Spectrum Analysis:

In statistical signal processing, the goal of spectral density estimation is to estimate the spectral density (also known as the power spectrum) of a random signal from a sequence of time samples of the signal. Naturally speaking, the spectral density characterizes the frequency content of the signal. The purpose of estimating the spectral density is to detect any periodicities in the data, by observing peaks at the frequencies corresponding to these periodicities.

The methods most commonly used for spectral analysis are based on:

1. **Fast Fourier Transform:**
2. **Autoregressive (AR) modeling:**

In the frequency-domain methods, a power spectrum density (PSD) estimate is calculated for the RR interval series. The regular PSD estimators implicitly assume equidistant sampling and, thus, the RR interval series is converted to equidistantly sampled series by interpolation methods prior to PSD estimation. In the software a cubic spline interpolation method is used. In HRV analysis, the PSD estimation is generally carried out using either FFT based methods or parametric AR modeling based methods **[6]**. The advantage of FFT based methods is the simplicity of implementation, while the AR spectrum yields improved resolution especially for short samples. Another property of AR spectrum that has made it popular in HRV analysis is that it can be factorized into separate spectral components. The disadvantages of the AR spectrum are the complexity of model order selection and the contingency of negative components in the spectral factorization. Nevertheless, it may be advantageous to calculate the spectrum with both methods to have comparable results.

In this software, the HRV spectrum is calculated with FFT based Welch"s periodogram method and with the AR method. Spectrum factorization in AR method is optional. In the Welch"s periodogram method the HRV sample is divided into overlapping segments. The spectrum is then obtained by averaging the spectra of these segments. This method decreases the variance of the FFT spectrum.

The generalized frequency bands in case of short-term HRV recordings are the very low frequency (VLF, 0–0.04 Hz), low frequency (LF, 0.04–0.15 Hz), and high frequency (HF, 0.15–0.4 Hz). The frequency-domain measures extracted from the PSD estimate for each frequency band include absolute and relative powers of VLF, LF, and HF bands, LF and HF band powers in normalized units, the LF/HF power ratio, and peak frequencies for each band (see the below Table 1).

In the case of FFT spectrum, absolute power values for each frequency band are obtained by simply integrating the spectrum over the band limits. In the case of AR spectrum, on the other hand, if factorization is enabled distinct spectral components emerge for each frequency band with a proper selection of the model order and the absolute power values are obtained directly as the powers of these components. If factorization is disabled the AR spectrum powers are calculated as for the FFT spectrum. The band powers in relative and normalized units are obtained from the absolute values as described in Table 1.

Table 1: Summary of the HRV measures calculated by the software

Peak frequency	Hz	VLF, LF, and HF band peak frequencies
Absolute power	ms^2	Absolute powers of VLF, LF, and HF bands
Relative power	%	Relative powers of VLF, LF, and HF bands VLF[%] = VLF[ms^2]/total power [ms^2] x 100% LF[%] = LF[ms^2]/total power [ms^2] x 100% HF[%] = HF[ms^2]/total power [ms^2] x 100%
Normalized power	n.u.	Powers of LF and HF bands in normalized units LF[n.u.] = LF[ms^2]/(total power [ms^2] – VLF [ms^2]) HF[n.u.] = HF[ms^2]/(total power [ms^2] – VLF [ms^2])
LF/HF		Ratio between LF and HF band powers

3.2. Normal condition based on power spectrum

According to medical terminology High Frequency (HF) and Low Frequency (LF) are compared. Medical journal (*Journal of Applied Physiology 71(3): 1136-42*) says if HF is greater than LF then the person is healthy, otherwise the person is unhealthy. i.e., In other words, HF is directly proportional to the healthy condition and LF is inversely proportional to the healthy condition.

4. Methodology
4.1Selection of the patients

In the present study and effort was made to randomly select patients from JIPMER hospital in India. patients were selected by ECG recording. 30 pregnancy womesn blood pressure after delivery (Group A) and before delivery with Blood Pressure (Group B) consented to have their ECGs recorded in a relaxed supine position for 60 minutes. To ensure accuracy, disturbances such as noise due to interference from cable, respiration, and muscle movements are removed prior to recording.Nonlinear analysis of HRV was performed by using Power Spectrum Analysis.

4.2 Before delivery for pregnant women, Power Spectrum Analysis of heart rate variability are shown in the following diagram

Patient-1

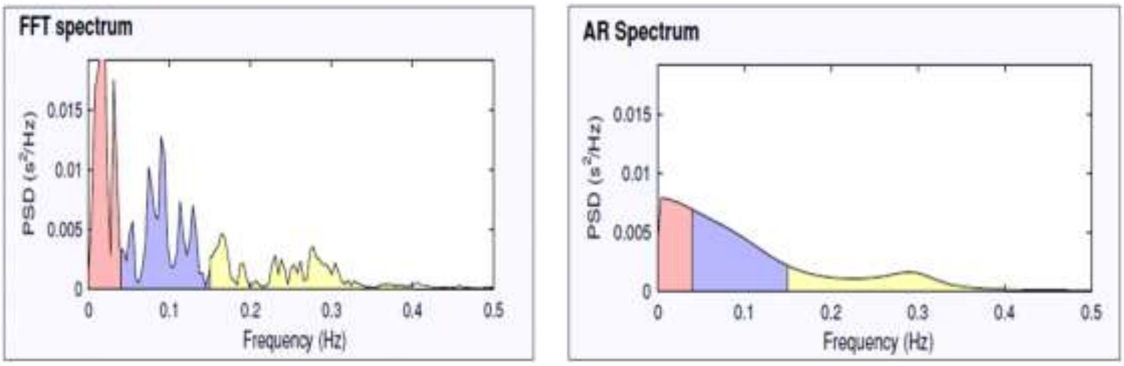


Figure 3: FFT & AR Spectrum for patient-1 before delivery

Table 2: FFT Frequency values for patient-1 before delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)

VLF (0 – 0.04 Hz)	0.0195	494	38.9	
LF (0.04 – 0.15 Hz)	0.0898	477	37.5	61.3
HF (0.15 – 0.4 Hz)	0.1641	301	23.7	38.7
Total		1272		
Ratio = LF/HF		1.584		

Table 3: AR Frequency values for patient-1 before delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)
VLF (0 – 0.04 Hz)	0.0039	294	28.0	
LF (0.04 – 0.15 Hz)	0.0430	505	48.1	66.7
HF (0.15 – 0.4 Hz)	0.1523	252	24.0	33.3
Total		1051		
Ratio = LF/HF		2.005		

Patient -2

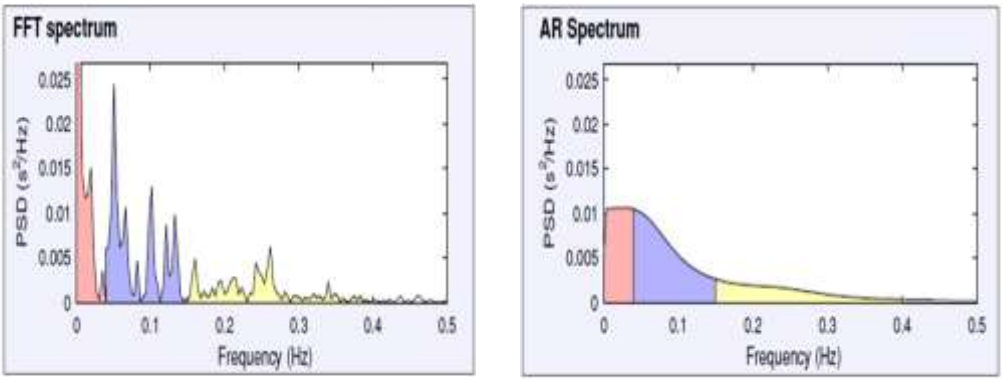


Figure 4: FFT & AR Spectrum for patient-2 before delivery

Table 4: FFT Frequency values for patient-2 before delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)
VLF (0 – 0.04 Hz)	0.0039	465	34.6	

LF (0.04 – 0.15 Hz)	0.0508	577	42.9	65.5
HF (0.15 – 0.4 Hz)	0.2617	303	22.6	34.5
Total		1345		
Ratio = LF/HF		1.901		

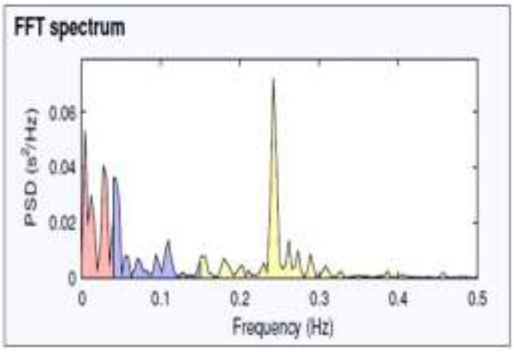
Table 5: AR Frequency values for patient-2 before delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)
VLF (0 – 0.04 Hz)	0.0273	412	29.5	
LF (0.04 – 0.15 Hz)	0.0430	679	48.5	68.8
HF (0.15 – 0.4 Hz)	0.1523	308	22.0	31.2
Total		1400		
Ratio = LF/HF		2.202		

In the last column of FFT & AR tables (both patints1 & 2), we observe that Normalised power reveals LF is almost double the HF. This implies patients are physically stressed before delivery.

4.3 After delivery for pregnant women, Power Spectrum Analysis of heart rate variability are shown in the below diagram

Patient -1



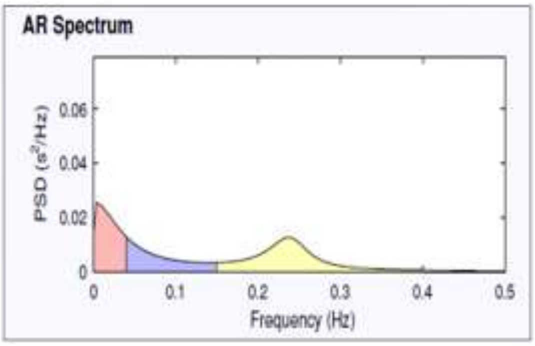


Figure 5: FFT & AR Spectrum after delivery

Table 6: FFT Frequency values for patient-1after finishing delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)
VLF (0 – 0.04 Hz)	0.0039	924	34.3	
LF (0.04 – 0.15 Hz)	0.0430	653	24.3	37.0
HF (0.15 – 0.4 Hz)	0.2422	1114	41.4	63.0
Total		2691		
Ratio = LF/HF		0.586		

Table 7: AR Frequency values for patient-1 after finishing delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)
VLF (0 – 0.04 Hz)	0.0039	779	32.0	
LF (0.04 – 0.15 Hz)	0.0430	603	24.8	36.4
HF (0.15 – 0.4 Hz)	0.2383	1055	43.3	63.6
Total		2437		
Ratio = LF/HF		0.572		

Patient -2

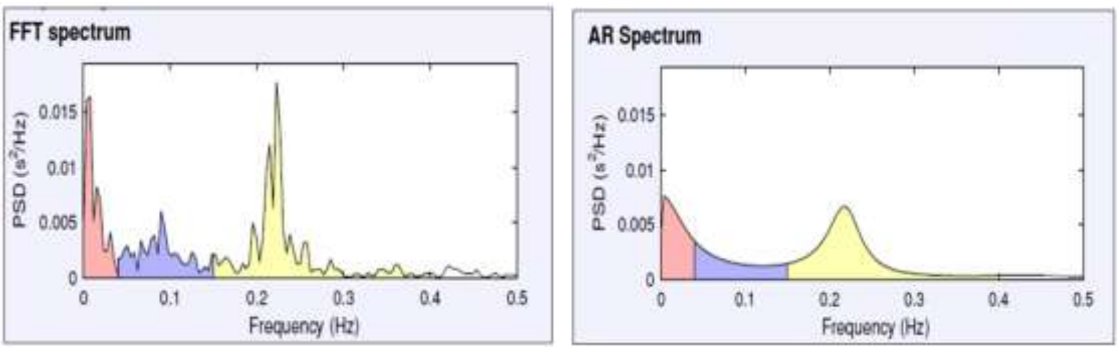


Figure 6: FFT & AR Spectrum for patient-2 after finishing delivery

Table 8: FFT Frequency values for student-2after finishing delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)

VLF (0 – 0.04 Hz)	0.0078	258	26.3	
LF (0.04 – 0.15 Hz)	0.0898	236	24.1	32.7
HF (0.15 – 0.4 Hz)	0.2227	486	49.6	67.3
Total		979		
Ratio = LF/HF		0.485		

Table 9: AR Frequency values for patient-2after finishing delivery

Frequency Band	Peak (Hz)	Power (ms2)	Power (%)	Power (n.u)
VLF (0 – 0.04 Hz)	0.0039	224	26.0	
LF (0.04 – 0.15 Hz)	0.0430	185	21.4	28.9
HF (0.15 – 0.4 Hz)	0.2188	455	52.6	71.1
Total		864		
Ratio = LF/HF		0.407		

`Here in the last column of FFT & AR tables (both patients 1 & 2), we observe that HF is almost double the LF. According to FFT & AR Spectrum patients are normal with respect to HRV. This implies patients are physically free after delivery.

5. Conclusion:

According to the Table-2&4 of FFT and Tables-3&5 of AR, we see that HF is less than LF in 3rd column. Hence we observed that Power Spectrum reveals Heart Rate Variability is not regular before delivery. That means there is physical irregularity with reference to the patients. And Table-6&8 of FFT and Tables-7&9 of AR, we see that HF is greater than LF in 3rd column. Hence we observed that power spectrum reveals that the Heart Rate Variability is regular after delivery. That means patient physically free.

In general power spectrum analysis reveals about HRV with respect to physical stress awareness using Autoregressive spectrum and Fast Fourier transform spectrum we observe the same thing. Using FFT and AR power spectrum analysis, one can observe physical stress, physical stability, alertness and health condition etc. In short it is widely used in medical diagnosis and medical observation.

6. References

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