Validation of magnetic therapy efficiency by ECG signal processing and HRV analysis

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Abstract *- A sensitive and difficult problem is the identification and correlation of changes in physiological parameters in the case of a person exposed to electromagnetic fields. Based on ECG recordings made before during and after magneto-therapy session, we determined and represented heart rate variability (HRV). We made both time domain and frequency domain HRV analysis in order to identify some differences due to the magnetic field exposure.*

Keywords – *signal processing, HRV analysis, magnetic field, frequency domain, vagal ratio.*

1. INTRODUCTION

The human body is the permanent headquarters of signals spontaneous, complex and induced by external stimuli, also known under the name of "bio signals". Decoding them provides information about the structure, evolution, and relationships between the characteristic parameters.

Due to new type electrocardiograms, digital, high frequency, knowledge of physiological and pathophysiological correlation of HRV and the ability to predict the evolution were improved.

2. METHODOLIGY

2.1. Theoretical premises

As is known, any external physical agent having an effective amount of potency can influence the ionic balance of the cells, modifying cell membrane permeability, causing ergo tropic, anabolic (energy-regenerating) reactions.

In medicine, the magnetic field is used, both for the diagnosis of a disease and for therapy. In recent years, a series of studies have been conducted on the effects of low frequency electromagnetic fields, both in the continuous and pulsating fields, on the human body. It is known that the action of the magnetic field is exerted on the cell by ionization of protoplasmic molecules through intracellular metabolic changes as a direct result of magnetic field energy (or magnetic field result) or indirectly by the new substances resulting from the chemical modifications of the protein molecules cell [1], [2].

Magneto therapy can be very effective if it is indicated and applied correctly. Under certain conditions (e.g., chronic pain in degenerative joint diseases), this method has proved effective as a therapy with long-lasting therapeutic effect, even when other methods of therapy have failed. It can also be recommended for use in combination with other methods of therapy, such as pharmacotherapy, whose effects are usually supported by magneto therapy.

A sensitive and difficult problem is the identification and correlation of changes in physiological parameters in the case of a person exposed to electromagnetic fields [3].

Our goal was to identify changes in HRV analysis of the ECG signal in subjects exposed to an electromagnetic field generated by therapeutic equipment, changes that validated the effectiveness of this treatment.

2.2. Materials and method

The study included 10 subjects who were adequately informed on each aspect of the measurement protocol and signed their consent to participate in the research.

For this study, the BTL 5920 was used (see Figure 1). It offers multiple and well-designed physiotherapy possibilities for professional use. Depending on the conditions, each system can be configured with one or more applicators, and there is a multitude of therapy programs tailored to each type of affection within the menu.

The ECG signal was acquired during the experiment using Biopac MP150, a system dedicated to biomedical signals.

Fig. 1 – BTL 5920 system

The 45 minute recording time was divided into 3 segments for the period before stimulation, during and after stimulation, as shown in Figure 2.

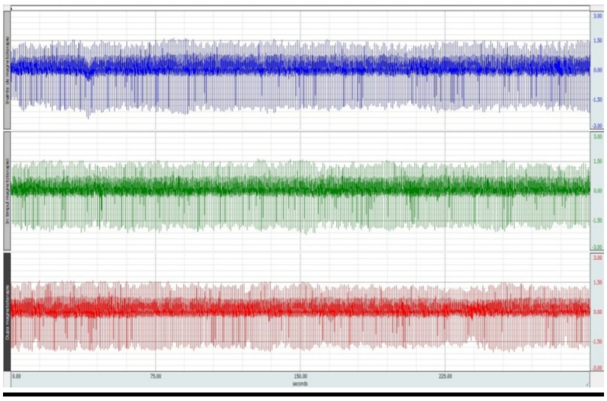

Fig. 2 – The division into three categories of registration: before (blue) during (green) after magnetic (red)

The recorded segments were processed to identify the QRS complexes and implicitly the calculation of the R-R intervals, but also because of the occurrence of disturbances due in particular to the influence of magneto therapy, but also because of motion artifacts or other kinds [4], [5], [6], [7].

2.3. ECG signal processing

Cardiac rhythm variability is the cyclical change in sine time depolarization, expressing spontaneous oscillations of successive RR intervals (Figure 3).

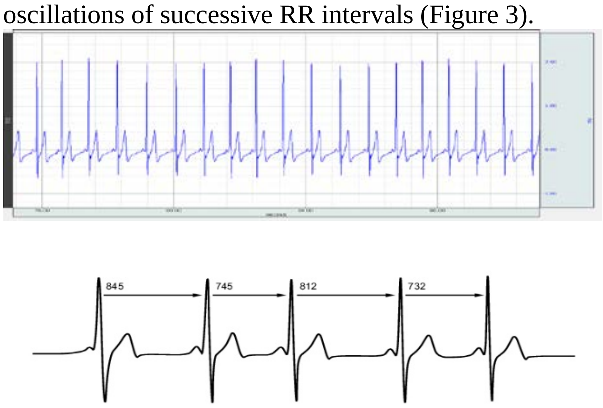

Fig. 3 – Cardiac rhythm variability

The algorithm of obtaining the data needed to perform the HRV analysis must follow a series of steps described in Figure 4.

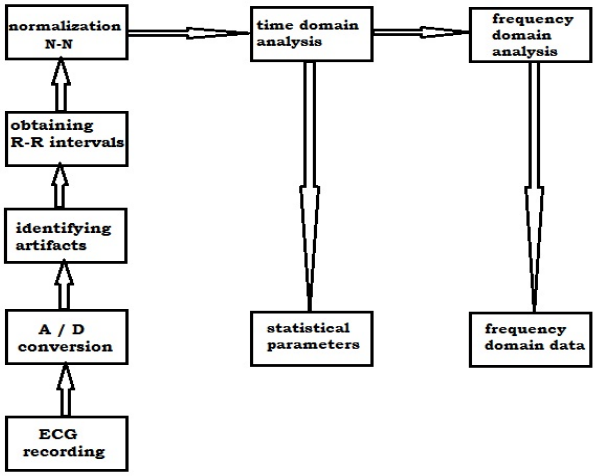

Fig. 4 – HRV analysis algorithm

Processing up to the normalization level was performed using the Ackqnowledge software of the Biopac equipment.

3. HRV ANALYSIS

The R-R interval can be graphically plotted against the time series for R-R time series analysis. However, in practice, ectopic beats are removed from the R-R series, leaving only the N-N series: normal sine waves. The minute fluctuations present in the N-N series allow the assessment of the influence of the nervous system components on the heart rate.

The simple variables in the field that can be calculated include the average of NN intervals, the heart pulse average, the difference between the longest and shortest NN interval, the difference between night and day heart rhythm, etc.

HRV parameters are calculated using two different methods [8] that are based on continuous sinus rhythm analysis on standardized electrocardiograms:

• Time domain, by analyzing the fluctuation of successive RR intervals;

• Frequency domain, by decomposing the signal represented by the RR interval in its frequency components that are quantified by their intensity of intensity (called "power").

3.1. Time domain analysis

The significance of different analyses of HRV is complex. Normal-to-normal (NN) intervals represent all the intervals between adjacent QRS complexes. Other time domain parameters of HRV, which are frequent used are: RMSSD – the square root of the mean squared differences of successive NN intervals; NN50 - the number of interval differences of successive NN intervals greater than 50ms; pNN50 - the proportion derived by dividing NN50 by the total number of NN intervals; RR Std - standard deviation of the RR intervals (Figure 5).

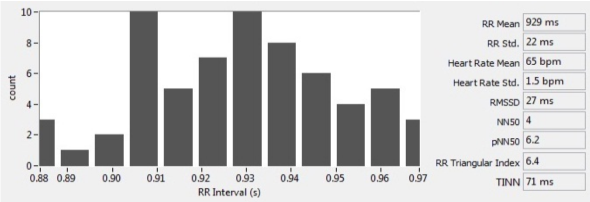

Fig. 5 – Time domain representation

3.2. Frequency domain analysis

The analysis in the frequency domain (spectral analysis) over the time domain has the advantage of appreciating not only the overall variability as a whole but also the specific oscillations of the investigated cardiovascular parameters, differentiating the sympathetic modulation from the parasympathetic. A common method of signal analysis in the frequency domain is made by determining the spectral power density of the direct Fourier transform. If x (n) defines the recorded periodic signal, discrete Fourier transform of x (t) is:

$$X_k = \sum_{n=0}^{N-1} x(n)\ e^{-i2\pi kn} \qquad (1)$$

In the frequency domain, we mainly followed the representation of three periodic components: basal, sympathetic and vagal.

Thus:

- very low frequency component (VLF) Very Low Frequency (VLF), 0.02 -0.04 Hz;

- low frequency spectral component (LF - Low Frequency): 0.04-0.15 Hz, characterizing the maximum of sympathetic activity;

- high frequency spectral component (HF): 0.15-0.40 Hz, expressing the influence of parasympathetic innervation;

- basal spectral component (BF - Basal Frequency) 1-1.5 Hz.

The spectral representation in the graph below (Fig. 6) is illustrative to understand this kind of representation in the frequency range of frequency cardiac variability.

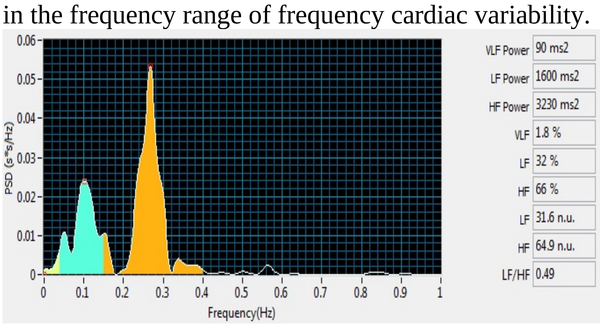

Fig. 6 – Frequency domain representation

Assessing the effectiveness of therapy were calculated HRV ratios: sympathetic and vagal and are derived as follows. Reporting a sum for a frequency range when computing the power in an individual band has been implemented as follows:

Given a frequency range f_{low} , f_{high} define the set S of all samples of the PSD.

$$where \qquad S = \{PSD(f_{low}),\ldots, PSD(f_{high})\}. \qquad (2)$$

Define the sum of the power within the frequency range as:

where

$|S|$ = is the set magnitude, that is, the number of elements in the set.

This applies the scaling factor to a sum of the frequencies in the frequency range, with the magnitudes at the endpoints divided by 2. The VLF section was included in the ratios.

$$s(f_{low}, f_{high}) = \left(\frac{S_1}{2} + \sum_{i=2}^{i=|S|-1} S_i + \frac{S_{|S|}}{2} \right) \times \frac{(f_{high} - f_{low})}{|S|-1} \qquad (3)$$

Define:

$$s_{VLF} = s(vlf_{low}, vlf_{high}) \qquad (4)$$

$$s_{LF} = s(lf_{low}, lf_{high}) \qquad (5)$$

$$s_{HF} = s(hf_{low}, hf_{high}) \qquad (6)$$

The new VLF ratio is:

$$\text{ratio}_{VLF} = \frac{s_{vlf}}{s_{vlf} + s_{lf} + s_{hf}} \qquad (7)$$

The new sympathetic ratio is defined as:

$$\text{ratio}_{LF} = \frac{s_{lf}}{s_{vlf} + s_{lf} + s_{hf}} \qquad (8)$$

The new vagal ratio is defined as:

$$\text{ratio}_{HF} = \frac{s_{hf}}{s_{vlf} + s_{lf} + s_{hf}} \qquad (9)$$

4. RESULTS AND DISCUTIONS

Referring to time domain analysis, we determined some statistical parameter and we observed a sensible increase of the variability during magneto therapy. These differences can be seen in the data in Table 1, these parameters being calculated for recording before, during and after magneto therapy.

Table 1 – Table description

	Before	During	After
Rrmin	0,7000	0.6940	0.6960
Rrmax	1,0400	1.0780	1.1840
RRmed	0,8342	0.8625	0.9072
RRstd	0,0519	0.0664	0.0898
RMSSD	31,87	47,65	55,39
NN50	79	82	89

Depending on the used signal type and the frequency of the magnetic stimulation, it was observed some change in frequency domain patterns. It was also represented HRV main spectral components, obtaining an evident decrease of the low frequency to high frequency ratios during magneto therapy session.

Fig. 7 – Frequency domain representation for all 3 situations (before, during and after magneto therapy)

Regarding sympathetic ratio was observed an increasing trend in vagal expense ratio for the three cases analyzed. (Figure 8)

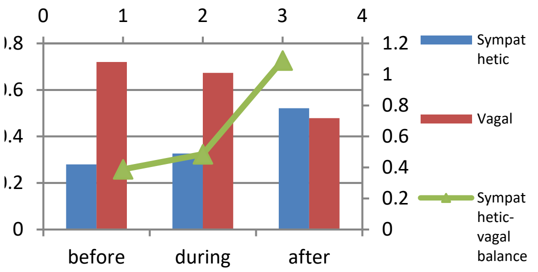

Fig. 8 – Frequency domain representation

5. CONCLUSIONS

The identified phenomena, demonstrated from the perspective of the experiments performed, are an appropriate support for the development of immediate plans or decisions regarding the validation of this method of therapy.

An understanding of the modulating effects of neural mechanisms on cardiac activity was developed by spectral analysis of HRV. Vagal affection activity is a major contributor to the HF component, as observed in both clinical and experimental situations.

Making the mean of the spectral components obtained from sequential time periods, allows minimizing the error imposed by the analysis of very short segments. A display of bands related to continuous power spectra (e.g. over 15 minutes) can help confirm changes that are safe for a particular physiological situation.

REFERENCES

1. Baldi E., Baldi C., Lithgow B.J., ”A pilot investigation of the effect of extremely low frequency pulsed electromagnetic fields on humans' heart rate variability”, Bioelectromagnetics, vol. 28, no.1, p. 64 – 68, 2007
2. Ciorap M., Andrițoi D., Ciorap R., David V., Corciova C., ”Study of Pulse Magnetotherapy Effects on Brain Electrical Activity”, International Conference and Exposition on Electrical and Power Engineering, 25 - 27 Oct. Iași, p. 668-671, 2012, (DOI:10.1109/ICEPE.2012.6463856);
3. Andrițoi D., David V., Ciorap R., Branzilă M., “Recording and Processing ECG Signal During Magnetotherapy Procedures”, Environmental Engineering and Management Journal, vol.12, no. 6, p. 1231-1238, 2013.
4. David V., Salceanu A., Ciorap R., “Acquisition and Analysis of Biomedical Signals in Case of Peoples Exposed to Electromagnetic Fields in Pervasive and Mobile Sensing and Computing for Healthcare“, In: *Pervasive and Mobile Sensing and Computing for Healthcare*. *Technological and Social Issues*, Mukhopadhyay S.C, Postolache O.A. (Eds.), Springer, 269-295, 2013;
5. Adochiei N.I., David V., Tudosa I., “Methods of electromagnetic interference reduction in electrocardiographic signal acquisition“, Environmental Enineering and Management Journal, **10**, p. 553-559, 2011
6. Pomazan V. M., Petcu L. C., Sintea S. R. , Ciorap R., “Active Data Transportation and Processing for Chronic Diseases Remote Monitoring”, International Conference on Signal Processing Systems (ICSPS 2009), 15-17 May Singapore, p.853-857, 2009
7. Ciorap R., Andritoi D., Pomazan V. M., Petcu L., Ungureanu F., Zaharia D., (2009), ”E-health system for monitoring of chronic diseases”, World Congress on Medical Physics and Biomedical Engineering, Munich, Germany, 7 - 12 September 2009, IFMBE Proceedings, 25 (5), p. 259-262, 2009, (DOI: 10.1007/978-3-642-03904-1-72)
8. Heart rate variability- *Standards of measurement, physiological interpretation, and clinical use*, European Heart Journal, Vol. 17, March 1996, 354-381.

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