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BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ
ÚSTAV AUTOMATIZAČNÍ A MEŘÍCÍ TECHNIKY

FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
DEPARTMENT OF CONTROL AND INSTRUMENTATION

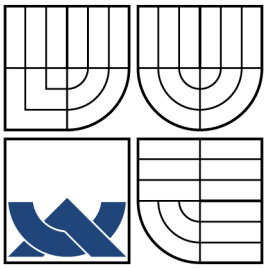
INFLUENCE OF AUTONOMIC NERVOUS SYSTEM IN THE INDUCIBILITY OF ATRIAL FIBRILLATION.

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

AUTOR PRÁCE
AUTHOR

MARTINA ŠRUTOVÁ

BRNO 2008



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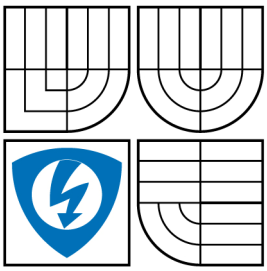

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VLIV AUTONOMNÍHO NERVOVÉHO SYSTÉMU NA VZNIK FIBRILACE SÍNÍ

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AUTHOR
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VEDOUCÍ PRÁCE
SUPERVISOR
Ing. JANA BARDOŇOVÁ, Ph.D.
Dr. JOSÉ MILLET ROIG

BRNO 2008

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

Fakulta elektrotechniky a komunikačních technologií

Ústav biomedicínského inženýrství

Bakalářská práce

bakalářský studijní obor
Automatizační a měřicí technika

Studentka: Martina Šrutová ***ID:*** 77995
Ročník: 3 ***Akademický rok:*** 2007/2008

NÁZEV TÉMATU:

Influence of autonomic nervous system in the inducibility of atrial fibrillation.

POKYNY PRO VYPRACOVÁNÍ:

Atrial fibrillation (AF) is the most common sustained rhythm disturbance. Various experimental and clinical observations suggest changes in sympathetic and vagal neural regulatory mechanisms play a critical role in altering cardiac electrical properties and favor the occurrence of arrhythmic events. The aim of this study is to investigate changes in sympatho-vagal balance 5, 10 and 15 minutes before the initiation of AF.

Methods: Six morgel dogs were included in this study. A pacemaker was connected to the left atrium and during 24 hours an ectopic focus was emulated (train impulses) each 30 minutes. Holter signals were recorded for off-line analyzed using Matlab 7 (The Mathworks, Inc., Natick, USA). Each 30 minutes segment will be classified as inducible or not inducible according to the presence of AF after the atrial pacing. QRS complexes will be detected and RR series will be constructed. Heart Rate Variability (HRV) parameters will be evaluated and analyzed to elucidate their influence in the induction or not of AF.

DOPORUČENÁ LITERATURA:

[1] Guidelines: Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. European Heart Journal 1996;17, 354-381.

[2] Seil Oh, Youhua Zhang, Steve Bibevski, Nassir F. Marrouche, Andrea Natale, Todor N., Mazgale: Vagal denervation and atrial fibrillation inducibility: Epicardial fat pad ablation does not have long-term effects. Heart Rhythm 2006;3:701-708.

[3] Marco Bettoni, Marc Zimmermann: Autonomic Tone Variations Before the Onset of Paroxysmal Atrial Fibrillation. Circulation 2002;105:2753-2759.

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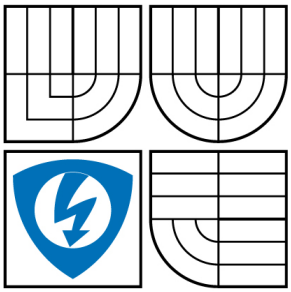

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Fakulta elektrotechniky a komunikačních technologií

Ústav biomedicínského inženýrství

Termín zadání: 1.2.2008 ***Termín odevzdání:*** 15.7.2008

Vedoucí práce: Ing. Jana Bardoňová, Ph.D.

prof. Ing. Pavel Jura, CSc.
předseda oborové rady

ABSTRAKT

Cílem této práce je zjištění změn předcházejícím fibrilaci síní. Pozorována je rovnováha mezi sympatikem a parasympatikem.

Do experimentu výzkumného ústavu Cleavlendské kliniky bylo zapojeno šest psů různých ras. Signály EKG byly získány Holterovským 24hodinovým monitorováním. Pomocí 40 vysokofrekvenčních impulsů (TI) byla každých 30 minut vyvolávána AF. Z 24hodinového signálu byly extrahovány kratší epizody. Každá z těchto epizod obsahovala 10 minut předcházejících TI a 3 minuty následující po TI. Desetiminutové epizody byly zpracovány automaticky, byly detekovány QRS komplexy a RR intervaly a vypočteny HRV parametry. Přítomnost a délka trvání AF byly zjištěny manuálně z tříminutových intervalů následujících po TI.

Byla-li vyvolána AF o délce trvání kratší než 30 sekund došlo ve srovnání s epizodami bez výskytu AF k významným změnám tří HRV parametrů. HF parametr poklesl pro epizody s výskytem AF. LF parametr byl naopak vyšší v epizodách s AF. Pro AF delší než 30 sekund nebyly významné změny pozorovány.

Změny v epizodách s krátkou AF mohly být způsobeny změnami vlivu sympatiku a parasympatiku. Ke vzniku dlouhých AF je pravděpodobně zapotřebí i jiného vlivu, který nemusí nutně souviset s nervovým systémem. K dalším analýzám je zapotřebí většího množství signálů.

KLÍČOVÁ SLOVA

Fibrilace síní, inervace síní, autonomní nervový systém, variabilita srdečního rytmu

ABSTRAKT

The aim of this study is to investigate changes in sympatho-vagal balance before the initiation of AF.

Six mongrel dogs from the Cleveland Clinic foundation were included in this study. ECG was recorded for 24 hours using telemetric Holter monitoring. AF was periodically induced every 30 min. by applying brief bursts of 40 high-frequency atrial train impulses (TI). From the 24 hours signals' traces shorter data episodes were extracted. Each episode consisted of 10 minutes preceding the atrial burst, and 3 minutes following the (TI). The 10 minutes episodes were processed automatically to determine the QRS complexes and RR intervals, and to calculate the HRV parameters. The presence and the duration of AF were determined by manual examination in each of the 3 minutes intervals following the delivery of TI.

When the AF was generated, but episodes of AF were shorter than 30 seconds, three HRV parameters were significantly different than when AF was not generated. The HF component was lower in episodes that generated AF. The LF component was higher in episodes that generated AF. No significant differences were found when episodes of AF were longer than 30 seconds.

Short episodes of AF could be generated when a certain disorder between sympathetic and parasympathetic tone is present. However in order to be able to generate longer AF episodes it is necessary another component not necessary related to the nervous system. Further analysis with a higher number of dogs should be needed.

KEYWORDS

atrial fibrillation, atrial innervation, autonomic nervous system, heart rate variability

ŠRUTOVÁ, Martina. *Influence of autonomic nervous system in the inducibility of atrial fibrillation*. Brno: Vysoké učení technické v Brně, Fakulta elektrotechniky a komunikačních technologií, 2008. 44s.Vedoucí práce Dr. José Millet Roig, Ing.Jana Bardoňová, Ph.D..

PROHLÁŠENÍ

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ACKNOWLEDGEMENT

I would like to thank my supervisors Ing.Jana Bardoňová, PhD and Dr.José Millet Roig for giving me the opportunity to do this project and helping me in many ways. Special thanks to Andreu Martinez Climent for answering my questions and for his support during this work. Many thanks also belong to the group I.T.A.C.A. from Universidad Politecnica de Valencia and to the Department of Biomedical Engineering from Brno University of Technology.

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1. INTRODUCTION

From the last statistic of the European Heart Network is known that each year cardiovascular disease causes over 4,3 million deaths in Europe. It is nearly half of all deaths in Europe (48%). It is two times more deaths, than tumor diseases cause. The most often from the cardiovascular disease is heart stroke. It is the most serious side effect of atrial fibrillation (AF). Half of all strokes associated with atrial fibrillation are major and disabling [1].Treating atrial fibrillation is an important way to help prevent stroke. That's why the American Heart Association recommends aggressive treatment of this heart arrhythmia [2].

Atrial fibrillation is the most common sustained rhythm disturbance. Various experimental and clinical observation suggest changes in sympathetic and vagal neural regulatory mechanisms play a critical role in altering cardiac electrical properties and favor the occurrence of arrhythmic events. On the basis of this, hypotheses about an influence of autonomic nervous system in the inducibility of atrial fibrillation were established. The aim of this study is to investigate changes in sympatho-vagal balance before the initiation of AF [3].

Ablation of Ganglionic Plexi (GP) nervous terminations of the atria is becoming a common intervention in order to reduce the number of AF episodes. (ref Katritsis Anatomic Approach for Ganglionic Plexi Abllation in Patients with Paroxysmal Atrial Fibrillation.American Journal of Cardiology 2008 In press). However the role of autonomic nervous system in the initiation of AF episodes is not sufficiently understood. In the previous studies there were observed abrupt changes in sympatovagal balance in the last 5 minutes preceeding an episode of AF [3]. In some patients was found that the two mechanisms operate during different hours of the day and that sometimes there is an increase of sympathetic tone, and in same instances an increase of parasympathetic tone. Autonomic imbalance is probably more important than the vagal or sympatethic drive alone [3].

In this work the variations in autonomic nervous systems before the emulation of AF initiation episodes are evaluated by means of heart rate variability analysis (HRV). The clinical importance of HRV became appreciated in the late

1980s, when it was confirmed that HRV was a strong and independent predictor of mortality after an acute myocardial infarction [4]. A description of the analysis and their physiological correlates are described in section 3.

The capture number five contains the own realization of the measuring. For analysis are used 6 records (24 h ECG) from dogs. Interestingly, experiments, hypothesizing that in both humans and dogs similar nerves exist in the same location [5]. There are described the extraction of the signal to the episodes, processing of the signal and automatic measuring of HRV parameters. Changes in sympato-vagal balance are investigated during 10 and 5 minutes before the initiation atrial fibrillation. For each episode is measured the time of duration atrial fibrillation. All the values are elaborated and statistically analyzed. MATLAB 7.0 is used as a software platform for this study.

2. CARDIAC STRUCTURE AND FUNCTION

The heart is shaped roughly like a cone and consists of four muscular chambers. The right and left ventricles are the main pumping chambers. The less muscular right and left atria deliver blood to their respective ventricles. [6]

2.1 HEART AND BLOOD CIRCULATION

Deoxygenated blood is delivered to the heart through the inferior and superior vena cava, witch enter into the right atrium. Flow continues through the tricuspid valve orifice into the right ventricle. Contraction of the right ventricle propels the blood cross the pulmonic valve to the pulmonary artery and lungs, where carbon dioxide is released and oxygen is absorbed. The oxygen-rich blood returns to the heart through the pulmonary veins to the left atrium and then passes across the mitral valve into the left ventricle. Contraction of the left ventricle pumps the oxygenated blood across the aortic valve into the aorta, whereupon it is distributed to all other tissues of the body. (Fig. 2.1 and 2.2) [6]

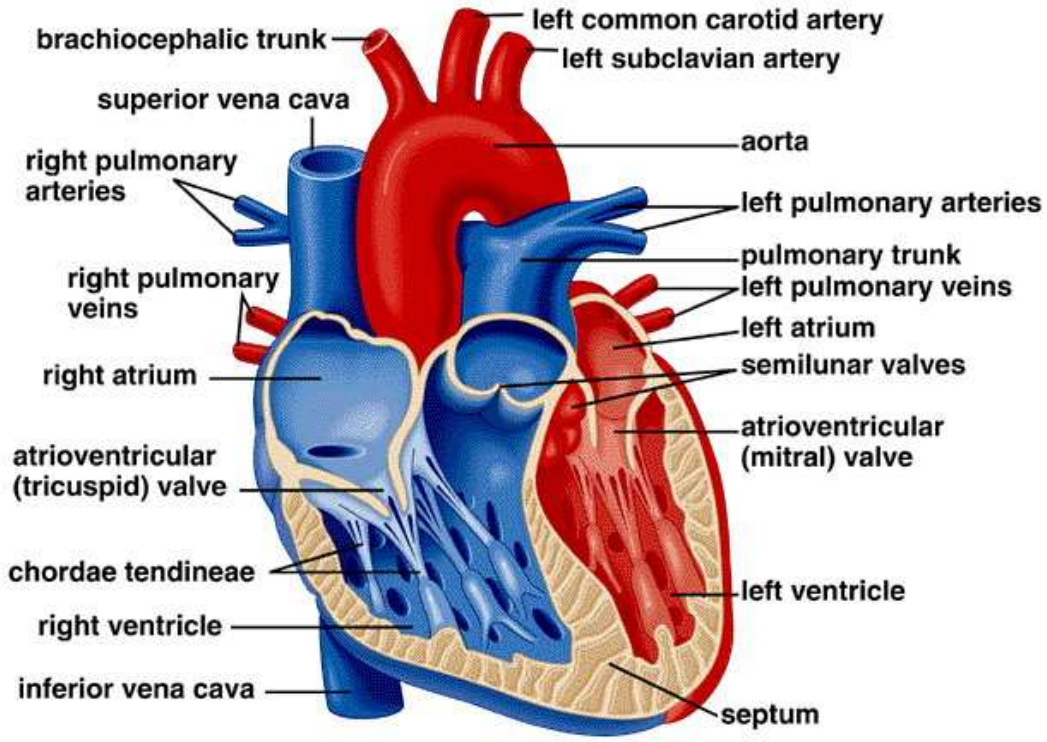

Fig 2.1 Internal view of heart [7].

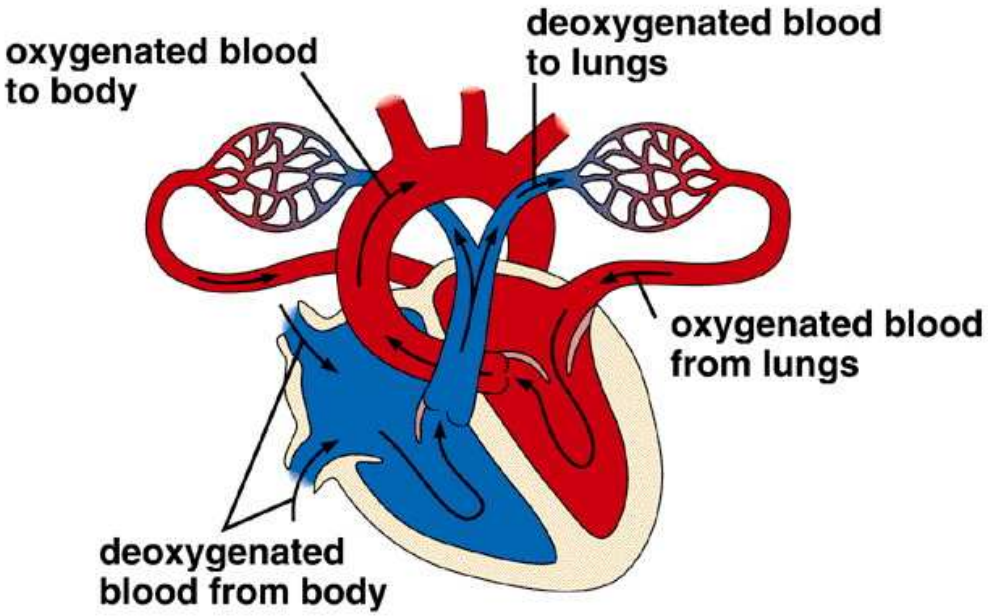

Fig 2.2 Path of blood through heart [7].

2.2 IMPULSE CONDUCTING SYSTEM

The impulse conducting system (Fig. 2.3) consists of specialized cells that initiate the heart beat and electrically coordinate contractions of the heart chambers. The **sinoatrial (SA) node** is small mass of specialized cardiac muscle fibers in the wall of the right atrium. It is located to the right of superior vena cava entrance and normally initiates the electrical impulse for contraction. The **atrioventricular (AV) node** lies beneath the endocardium in the inferoposterior part of the interatrial septum. Distal to the AV node is the **bundle of His**, which perforates the interventricular septum posteriorly. Within the septum, the bundle of His bifurcates into a broad sheet of fibers that continues over the left side of the septum, known as the **left bundle branch**, and a compact, cablelike structure on the right side, the **right bundle branch**.

Functionally, the left bundle branch is divided into an anterior and posterior fascicle and small branch to the septum. The anterior fascicle runs anteriorly toward the apex, forming a subendocardial plexus in the area of the anterior papillary muscle. The posterior fascicle travels to the area of the posterior papillary muscle; it

then divides into a subendocardial plexus and spreads to the rest of the left ventricle. The subendocardial plexuses of both ventricles send distributing **Purkinje fibers** to the ventricular muscle. Impulses within the His-Purkinje system are transmitted first to the papillary muscles and than throughout the walls of the ventricles, allowing papillary muscle contraction to precede that o the ventricles. This coordination prevents regurgitation of blood flow through the AV valves, as discussed above.

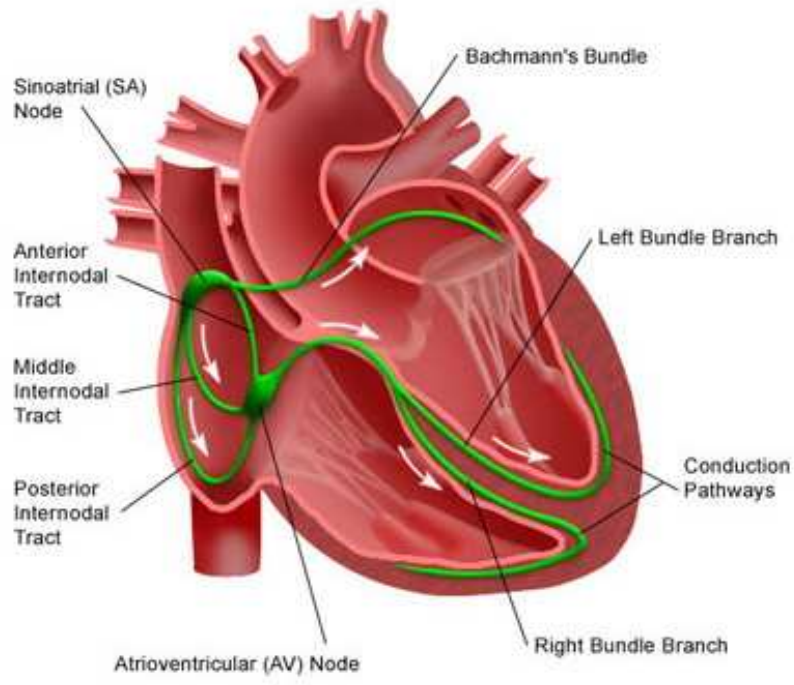

Fig 2.3 Electrical system of the heart [8].

2.3 CARDIAC INNERVATION

The heart is innervated by both parasympathetic and sympathetic afferent and afferent nerves. Stimulation of the vagus nerve (parasympathetic fibers) causes a decrease in the SA node rate

Stimulation of the vagus nerve (parasympathetic fibers) causes a decrease in the SA node rate (thereby decreasing the heart rate and force of contraction).

Stimulation via sympathetic fibers causes an increase in the SA node rate (thereby increasing the heart rate and force of contraction).[8] Preganglionic **sympathetic** neurons located within the upper five to six thoracic levels of spinal cord synapse

with second-order neurons in the servical sympathetic ganglia. Traveling within the cardiac nerves, these fibers terminate in the heart and great veseels. Preganglionic **parasympathetic** fibers originate in the dorsal motor nucleus of the medulla and pass as branches of the vagus nerve to the heart and great vessels. Here the fibers synapse with second-order neurons located in ganglia within these structures. A rich supply of vagal afferents from inferior and posterior aspects of the ventricles mediates important cardiac reflex, whereas the abundant vagal efferent fibers to the SA and AV nodes are active in modulating electrical impulse initiation and conduction. [6]

Heart rate and rhythm are under the control of the autonomic nervous system. The parasympathetic influence on heart rate is mediated via release of acetylcholine by the vagus nerve. The sympathetic influence is by epinephrine and norepinephrine. The vagal and sympathetic activity constantly interact. Parasympathetic influences exceed sympathetic effects probably via two independent mechanisms: cholinergically induced reduction of norepinephrine released in response to sympathetic activity, and a cholinergic attenuation of the response to a adrenergic stimulus. [4]

2.4 ATRIAL FIBRILLATION

The atrial fibrillation (AF) is one of the supraventricular arrhythmias. Although normally SA node maintains rate of about 60 beats per minute and 180-200 times per minute at peak exercise, there is a chaotic rhythm with an atrial rate about 350-600 discharges/min during the fibrillation. That’s why discrete P waves are not discernible on the ECG. Because discrete P waves are not visible on the ECG, the baseline shows low amplitude undulations punctuated by QRS complexes and T waves. If each atrial impulse were conducted to the ventricles, the extremely rapid ventricular rate would lead to ineffective cardiac contraction and rapid death (Fig. 2.5). This is prevented by the filtering function of the refractory tissue at the AV node. So the only some of the depolarizations are conducted to the ventricles, in a very irregular fashion. The average ventricular rate in untreated AF is approximately 160 bpm. [6] [9]

Fig 2.4 Normal ECG signal [10].

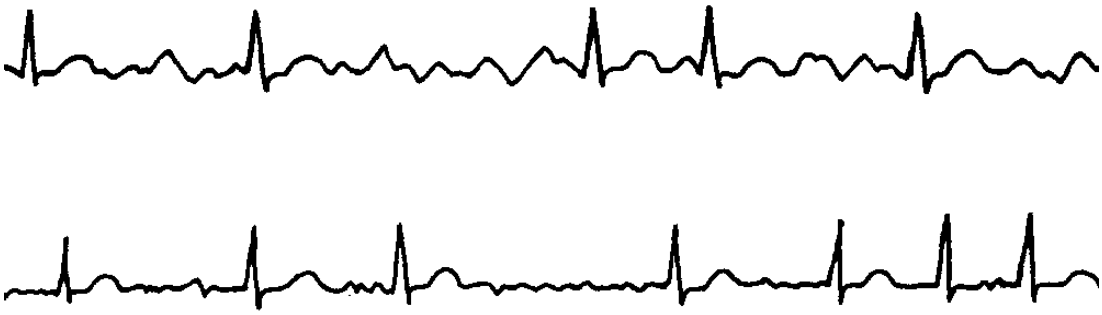

Fig 2.5 Two signals of atrial fibrillation. [10].

Several cardiac disorders predispose to AF, including coronary artery disease, pericarditis, mitral valve disease, congenital heart disease, congestive heart failure (CHF), thyrotoxic heart disease and hypertension. AF is dangerous mostly for two reasons: The first is that rapid ventricular rates may compromise cardiac output, resulting in hypotension and pulmonary congestion. The second reason is the absence of organized atrial contraction. It leads to stasis of blood in the atria and increases the risk of thrombus formation, particularly in the left atrial appendage. Embolization of left atrial thrombi is an important cause of stroke.

Treatment of AF therefore focuses on three aspects of the arrhythmia: 1) ventricular rate control, 2) attempts to restore sinus rhythm, and 3) assessment of the need for anticoagulation to prevent thromboembolism. But there are still some disadvantages of the pharmacological therapies. For example the anticoagulant drugs increase the risk of bleeding complications and the affects of antiarrhythmic drugs on the electrophysiology of the ventricles can themselves paradoxically lead to life-threatening rhythm disorders and increase mortality. [6] [9] [11] [12]

3. MEASURES OF HEART RATE VARIABILITY

The last two decades have been observed a significant relationship between the autonomic nervous system and cardiovascular mortality. HRV represents one of the most promising such markers and it has become the conventionally accepted term to describe variations of both instantaneous heart rate and RR intervals. The European Society of Cardiology and the North American Society of Pacing and Electrophysiology constituted a Task Force charged with the responsibility of developing appropriate standards. [4] The specific goals of this Task Force were to (1) standardize nomenclature and develop definitions of terms, (2) specify standard methods of measurement, (3) define physiological and pathophysiological correlates, (4) describe currently appropriate clinical applications, and (5) identify areas for future research.

3.1 TIME DOMAIN METHODS – STATISTICAL METHODS

The statistical time-domain measures are mostly based on the direct measurements of **normal-to-normal (NN) intervals** (that is, all intervals between adjacent QRS complexes resulting from sinus node depolarizations) or instantaneous heart rate. They can be derived from the differences between NN intervals. The simplest variable to calculate is **the standard deviation of the NN intervals (SDNN)**, that is, the square root of variance. Since variance is mathematically equal to total power of spectral analysis, SDNN reflects all the cyclic components responsible for variability in the period of recording. In many studies SDNN is calculated over a 24-hour period and thus encompasses short-term HF variations as well as the lowest-frequency components seen in a 24-hour period. As the period of monitoring decreases, SDNN estimates shorter and shorter cycle lengths. It also should be noted that the total variance of HRV increases with the length of analyzed recording. Thus, on arbitrarily selected ECGs, SDNN is not a well-defined statistical quantity because of its dependence on the length of recording period. In practice, it is inappropriate to compare SDNN measures obtained from recordings of different

durations. The most commonly used measures derived from interval differences include **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 50*ms*, and **pNN50**, the proportion derived by dividing NN50 by the total number of NN intervals. In the following work **RR intervals** were used instead of NN. It mean that were evaluated intervals between all QRS complexes. [4]

Definition of time domain analysis: MI, SD, RMSSD and %RR50.

$$MI = \frac{\sum_{i=1}^{n} t_i}{n}(ms) \qquad (3.1)$$

$$SD = \sqrt{\frac{\sum_{i=1}^{n} (MI - t_i)^2}{n-1}}(ms) \qquad (3.2)$$

$$RMSSD = \sqrt{\frac{\sum (t_i - t_{i-1})^2}{n-1}}(ms) \qquad (3.3)$$

$$\%RR50 = \frac{(Number\_of\,(t_i - t_{i-1}) > 50)}{n-1}(\%) \qquad (3.4)$$

MI	Mean interval.
n	Number of RR intervals.
SD	Standard deviation.
RMSSD	Root mean square successive differences.
RR50	The proportion of cycles during which the RR difference is > 50*ms* in percents.
ti	RR interval in *ms*.

3.2 FREQUENCY DOMAIN METHODS –

Methods for the calculation of power spectral density (PSD) may be generally classified as nonparametric and parametric. In most instances, both methods provide comparable results. The advantages of the nonparametric methods are (1) the

simplicity of the algorithm used (fast Fourier transform [FFT] in most of the cases) and (2) the high processing speed, while the advantages of parametric methods are (1) smoother spectral components that can be distinguished independent of preselected frequency bands, (2) easy postprocessing of the spectrum with an automatic calculation of low- and high-frequency power components with an easy identification of the central frequency of each component, and (3) an accurate estimation of PSD even on a small number of samples on which the signal is supposed to maintain stationarity. The basic disadvantage of parametric methods is the need of verification of the suitability of the chosen model and of its complexity (that is, the order of the model). [4]

Spectral Components

Short-term recordings: Three main spectral components are distinguished in a spectrum calculated from short-term recordings of 2 to 5 minutes: **VLF, LF, and HF components**. The distribution of the power and the central frequency of LF and HF are not fixed but may vary in relation to changes in autonomic modulations of heart period. The physiological explanation of the VLF component is much less defined. The measurement of VLF, LF, and HF power components is usually made in absolute values of power (milliseconds squared). LF and HF may also be measured in normalized units which represent the relative value of each power component in proportion to the total power minus the VLF component. The representation of LF and HF in normalized units emphasizes the controlled and balanced behavior of the two branches of the autonomic nervous system.

Long-term recordings: Spectral analysis also may be used to analyze the sequence of NN intervals of the entire 24-hour period. The result then includes a ULF component, in addition to VLF, LF, and HF components. But more about long-term recordings is beyond the scope of this work.

Definition of time domain analysis: LF, HF, LF/HF, LFnorm and HFnorm.

LF	Power in very low frequency range <= 0.04Hz in ms^2.
HF	Power in high frequency range <= 0.15-0.4Hz in ms^2.

LF/HF	Ratio LF [ms^2]/HF [ms^2].
LF norm	LF power in normalised units (*n.u.*).
	LF/(Total power-VLF)x100
HF norm	HF power in normalised units (*n.u.*).
	HF/(Total power-VLF)x100

Algorithmic standards and recommendations

The spectrum of the HRV signal is generally calculated either from the RR interval tachogram (RR durations versus number of progressive beats (Fig. 3.1)a,b) or by interpolating the discrete event series DES (the plot of RiRi-1 interval versus time), or by calculating the spectrum of the counts–unitary pulses as a function of time corresponding to each recognized QRS complex.

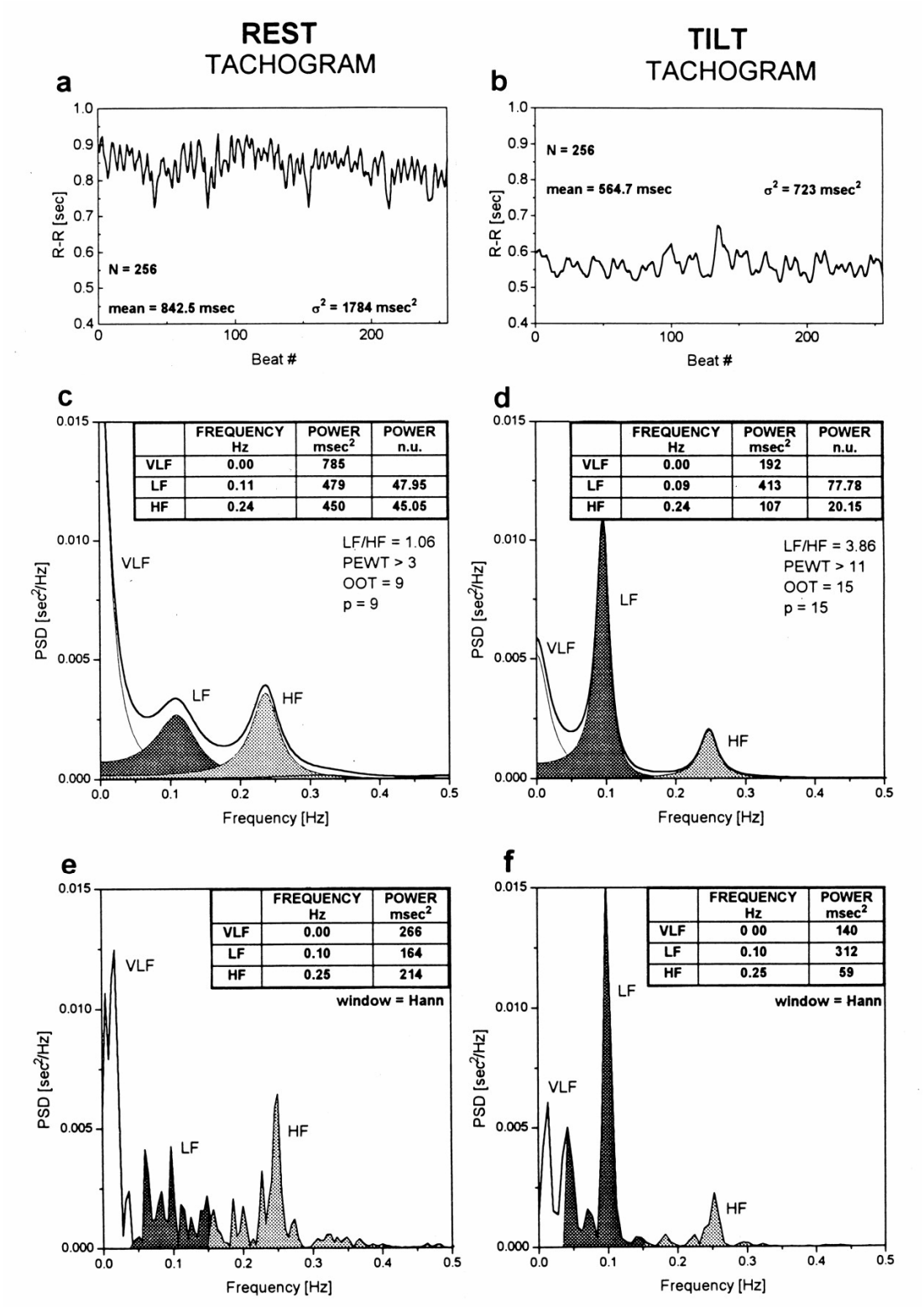

Fig 3.1 Interval tachogram of 256 consecutive RR values in a normal subject at supine rest (a) and after head-up tilt (b). The HRV spectra are shown, calculated

by parametric autoregressive modeling (c and d) and by a fast Fourier transform–based nonparametric algorithm (e and f). Mean values (m), variances (s^2), and the number (N) of samples are indicated. For c and d, VLF, LF, and HF central frequency, power in absolute value and power in normalized units (n.u.) are also indicated together with the order p of the chosen model and minimal values of the prediction error whiteness test (PEWT) and optimal order test (OOT) that satisfy the tests. In e and f, the peak frequency and the power of VLF, LF, and HF were calculated by integrating the power spectral density (PSD) in the defined frequency bands. The window type is also specified. In c through f, the LF component is indicated by dark shaded areas and the HF component by light shaded areas. [4]

3.3 PHYSIOLOGICAL CORRELATES OF HRV COMPONENTS

Vagal activity is the major contributor to the HF component. Disagreement exists in respect of the LF component. Some studies suggest that LF, when expressed in normalized units, is a quantitative marker for sympathetic modulations, other studies view LF as reflecting both sympathetic and vagal activity. Consequencly, the LF/HF ratio is considered by some investigators to mirror sympatho-vagal balance or to reflect sympathetic modulations. Physiological interpretation of lower frequency components of HRV (that is of the VLF and ULF components) warrants further elucidation. It is important to note that HRV measures fluctuations in autonomic inputs to the heart rather than the mean level of autonomic inputs. Thus both autonomic withdrawal and a saturatingly high level of sympathetic input lead to diminished HRV. [13] [4]

4. METHODS

4.1 DATABASE

Six mongrel dogs from the Cleveland Clinic foundation were included in this study. A pacemaker was connected to the left atrium and during 24 hours an ectopic focus was emulated (train impulses of high-frequency) each 30 minutes to evoke AF. These impulses were emulated during 30*s* with the frequency about 7*Hz* for the dogs number 1-4 and only 5s with frequency about 20*Hz* for dogs 5 and 6. Train impulses are visible in the ECG signal (Fig. 4.1 and 4.2)

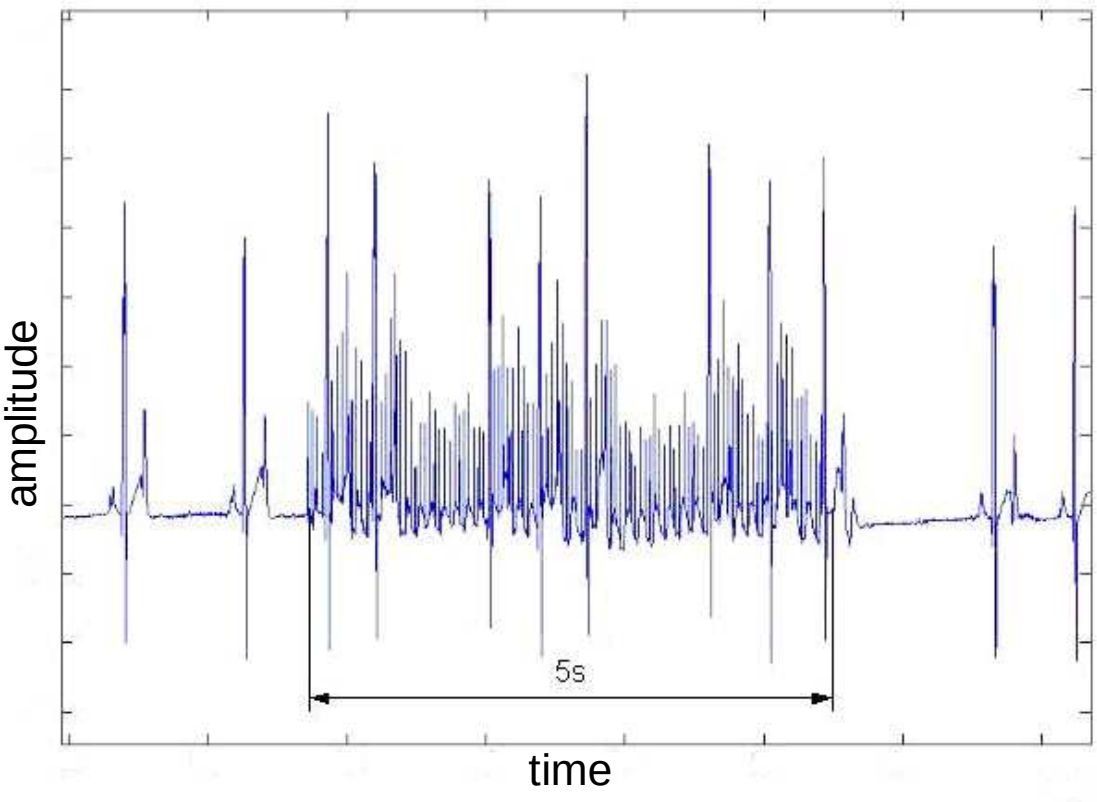

Fig 4.1 Train impulses of the duration 5s in the ECG signal (dog 6, episode 2)

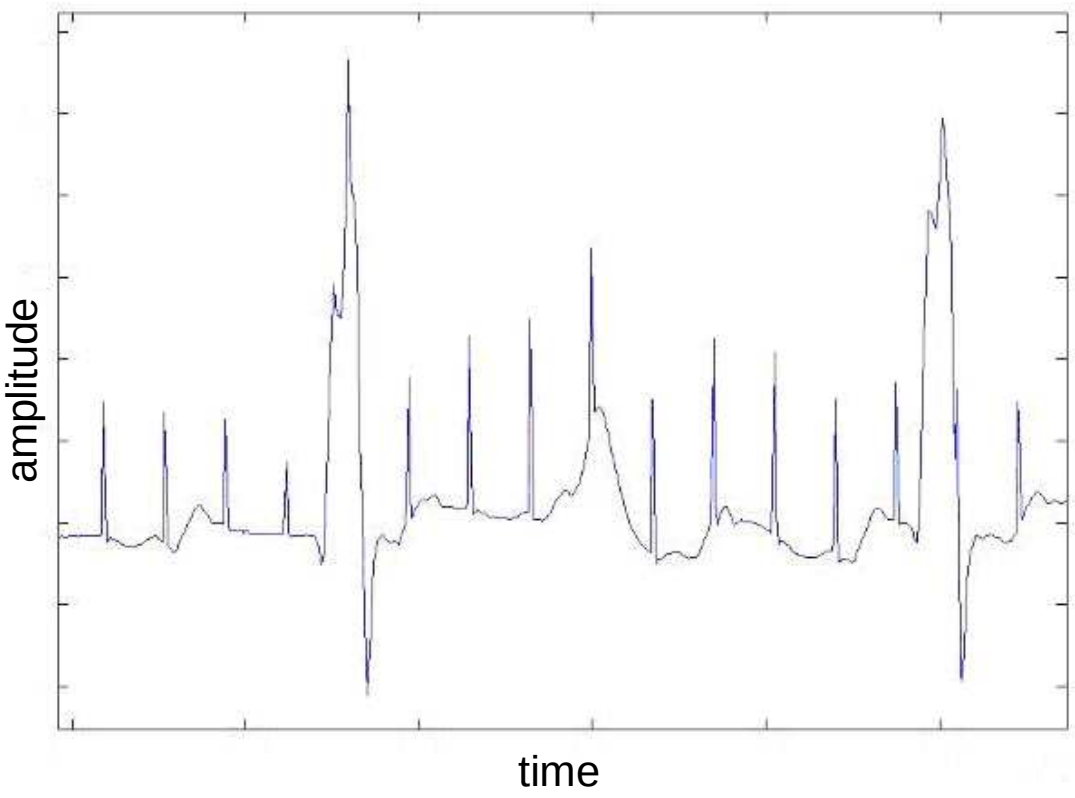

Fig 4.2 Detail of the first 16 trail impulses (dog 6, episode 2)

The protocol was approved by the institutional review board of the centre. Holter signals were recorded for off-line analyzed using Matlab 7 (The Mathworks, Inc., Natick, USA).

4.2 RR SERIES DETECTION

From the 24 hours signals 47 episodes each 30 min were extracted and split in two parts, 10 minutes before and 3 minutes after each train impulses (TI) (Fig 4.2). These two signals were saved with other parameters (sampling frequency, star time of the extraction, folder of the loaded signal). The episode number one includes the signal with the first TI, but only if there are enough samples before TI (ex: the first IT is found at 00:07:15, but the first episode is the signal with TI at 00:37:15). The time of the first TI and the exact time between two episodes were found manually,

they are different for each dog. The sampling frequency was 750*Hz*. The selected episodes of the 24 hours signals were loaded.

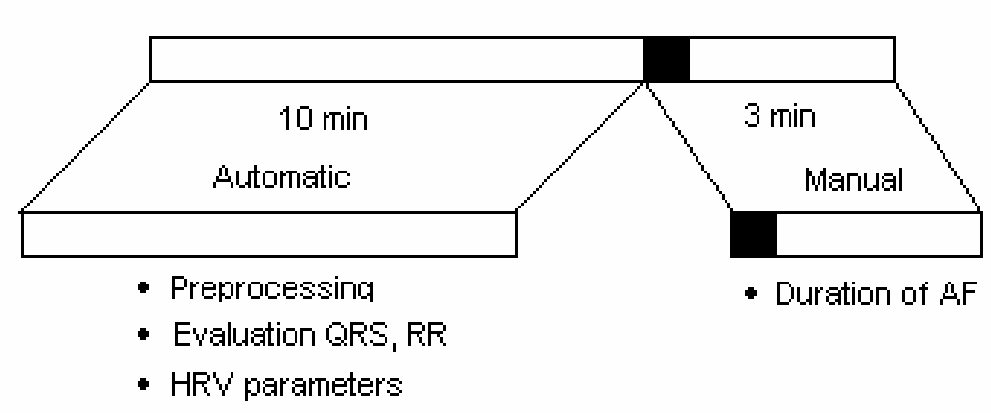

Fig 4.3 Diagram of the signal prosessing.

The intervals of 10 minutes before the atrial ectopic emulation were automatically preprocessed by the MIT function It consisted in the elimination of the base line and filtering to remove noise and respiratory artefacts. QRS complexes were detected and clasified. This function for the detection R waves was based on the Tompkins algorithm [14]. The signal of the input is resampled by this function. The new sampling rate was 256*Hz*. In this variable the ectopic (Fig. 4.4) beats and artefacts were detected and only time between two normal QRS complexes were used.

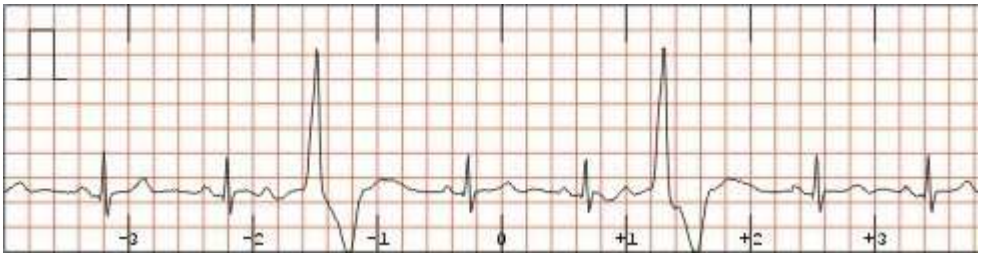

Fig 4.4 Electrocardiogram: Ventricular Trigeminy ; the ventricular ectopic beats (three and six) are separated by two sinus beats. [13]**.**

In the order to use the MIT algorithms signal were divided in 10 second sections. This reduces the effect of noise segments (Fig. 4.5).

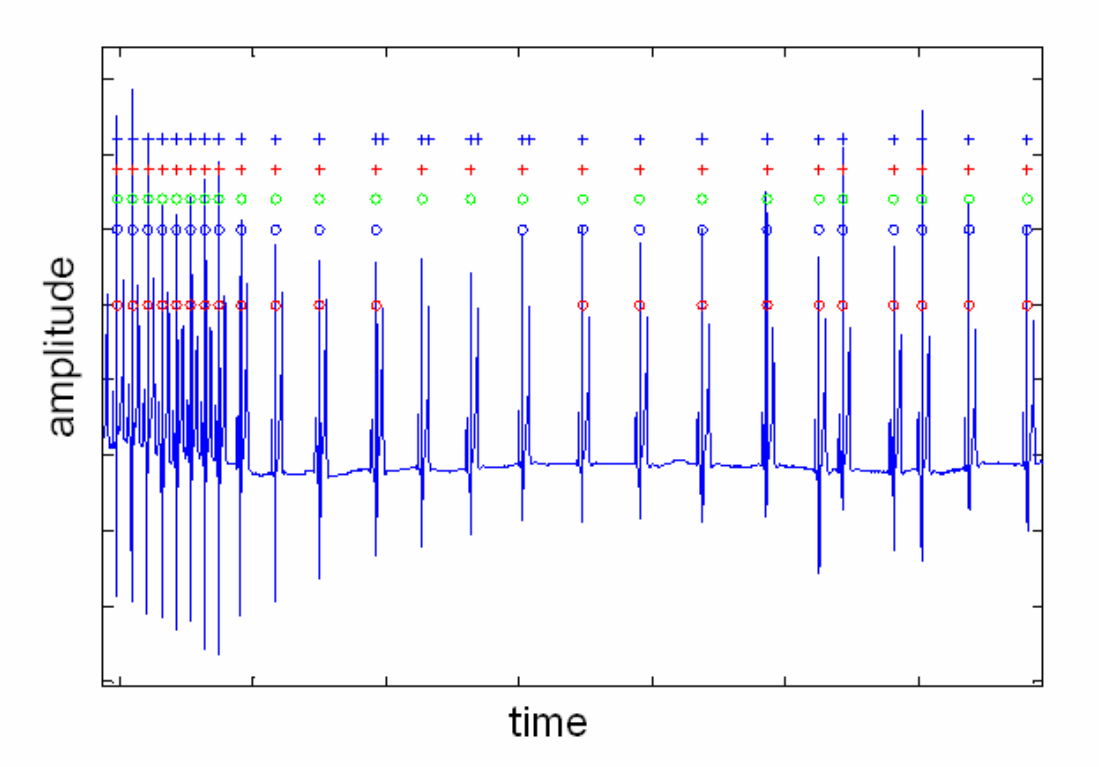

Fig 4.5 Detection QRS complexes with the different short time(dog5, episode 37: o red – without short time, o blue – short time 30s, o green – short time 15s, + red – short time 10s, + blue – short time 5s).

4.3 HRV MEASUREMENTS

Finally RR intervals were evaluated included ectopic beats and artefacts. HRV parameters were counted from the above mentioned RR intervals. For the correct results some of the RR intervals are omitted: 1) the intervals longer than 2s, because after longer time impulse is created by AV node [16]. 2) the shorter intervals than 200ms, because it's physiologically impossible to create two impulses during so short time, it means, that P-wave or T-wave was probably detected, this incorrect detection influences also the next interval 3) because of this the next interval was also omitted. The formulas from Section 3 were used to count the time and frequency domain parameters. For the calculation of the frequency domain parameters, the data were converted to the frequency domain by means an algorithm developed previously in the group.

There were observed the common differences and changes of the time and frequency domain parameters. From the time domain parameters there were: MI, mean interval; SD, standard deviation; RMSSD, root mean square successive differences; RR50, the proportion of cycles during which the RR difference is > 50 ms. Frequency domain parameters are: LF, power in very low frequency range <= 0.04Hz in ms^2; HF, power in high frequency range <= 0.15-0.4Hz in ms^2; LF/HF, ratio LF [ms^2]/HF [ms^2]; LF norm, LF power in normalised units (*n.u.*), LF/(Total power-VLF)x100; HF norm, HF power in normalised units (*n.u.*), HF/(Total power-VLF)x100.

4.4 STABILITY TEST

In order to test the stability of the HRV measurements the signal of ten minutes before TI was split in two parts of five minutes (Fig 4.6). There were compared only the values of the same parts. To confirm reproducibility of the results, the values of the parameters from the first part should be similar with the parameters of the second part. The tendency of these parameters from 10 minutes analysis should be same like tendency of parameters for each part from 2x5min analysis.

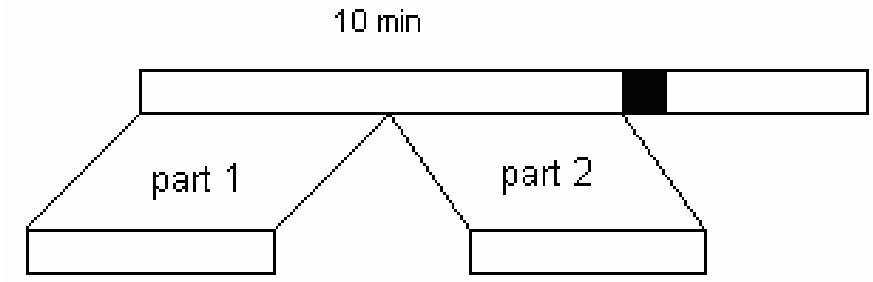

Fig 4.6 Dividing into the two parts for 2x5min analysis.

4.5 AF DETECTION

The presence of AF after TI was evaluated manually in the program, which was created as Matlab GUIDE. There was possible to figure signal of all episodes for each dog. Two buttons for activation the cursors were used for measuring of the duration AF (displayed in the column the time of fibrillation). Guarantee of subjective design is set by the buttons YES, NOT SURE and NO. To save all the values the button SAVE must be pushed (Fig. 4.7). The following parameters of AF were evaluated.

Parameters of fibrillation analysis.

time	Duration of the fibrillation in *s*.
sub	Guarantee of subjective design
	(1 80-100%
	2 50-79%
	3 0-49%).
detailes	Specification of the problem.
type of AF	Group of the duration AF
	(0 0s
	1 less than 10s
	2 10s-30s
	3 30s-3min
	4 longer than 3min

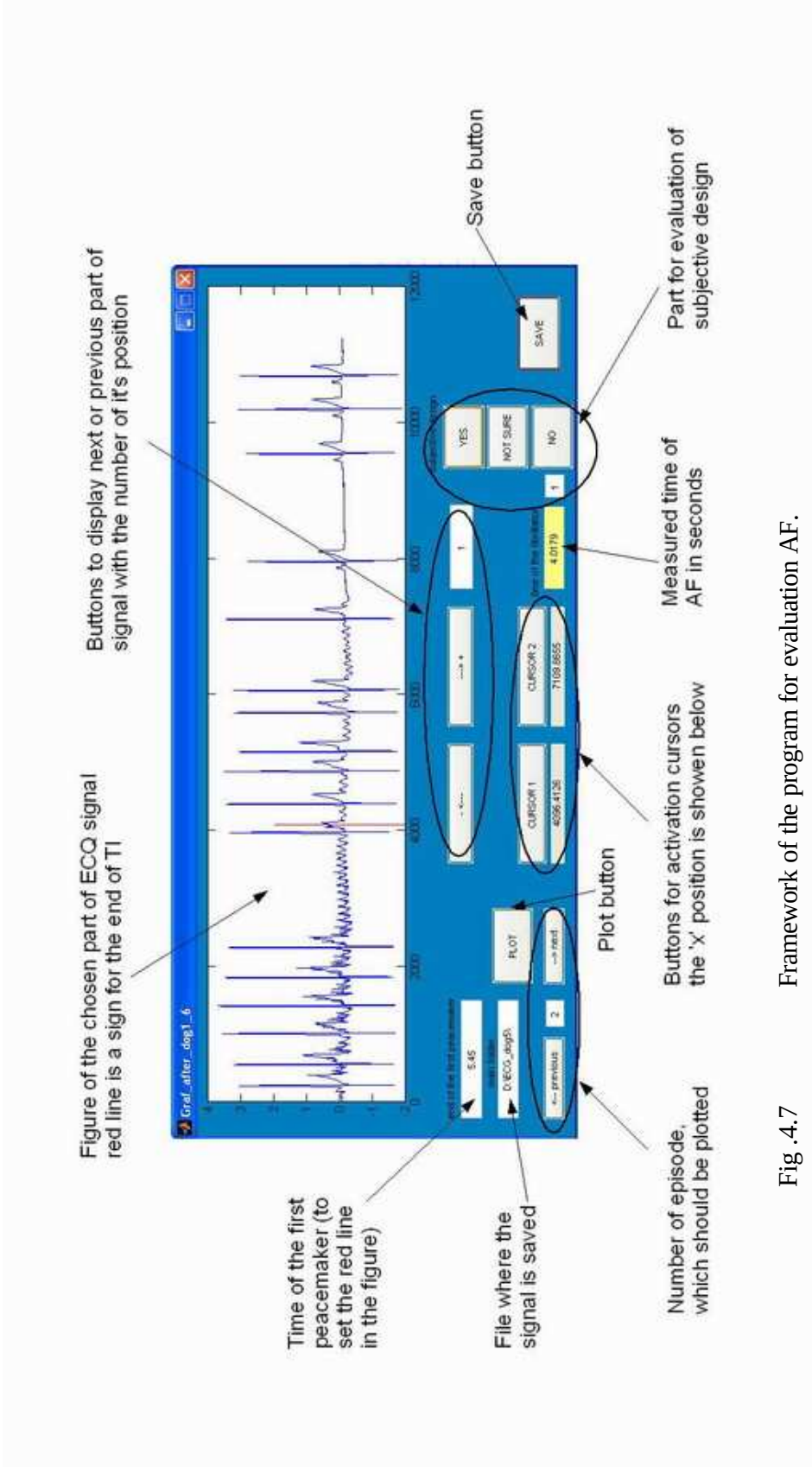

Fig .4.7 Framework of the program for evaluation AF.

4.6 STATISTICS

Student t-test was used to estimate the significance of differences between the HRV parameters. The results with significance lower than 0,05 were considered as significant. In the section of 10 minutes analysis there were compared the results for groups of AF episodes with the episodes of no AF. The section of 2x5 minutes analysis should support the tendency and stability of the previous results. There were made the same analysis for first 5 minutes and second 5 minutes independently. For the following analysis was used Matlab function ttest2. Data are presented as Mean ± Std.

5. RESULTS

5.1 AF INDUCIBILITY

The results of the six dogs were evaluated. All episodes were classified into several groups according to the duration of AF. Numbers of episodes of each dog are shown in the table below (Tab. 5.1).

The numbers of episodes depending on the time of duration AF						
type of AF	0	1	2	3	4	NaN
time of fibrillation	0s	<10s	10-30s	30s-3min	>3min	NaN
dog 1	25	0	2	7	2	9
dig 2	41	0	0	1	1	1
dog 3	41	0	0	0	0	3
dog 4	44	1	0	0	0	0
dog 5	26	9	1	6	3	0
dog 6	8	5	7	6	20	1

Tab 5.1 Numbers of episodes in the groups of duration AF (0s, <10s, 10-30s, 30s-3min, >3min, NaN)

More than 5% of episodes were not included in the evaluation (NaN), because of the noise in the signal after peacemaker. There was no AF episode detected during 24 hours in the signal of the dog number 3 and only one fibrillation for dog number 4.

5.2 10 MINUTES RESULTS

In the following table (Tab. 5.2), there are compared just values for episodes where AF was (AF) and where was not (NO AF) detected. It was visible that the changes between these two groups were not significant.

DOGS ALL:Changes in HRV parameters for AF			
Duration AF	NO AF	AF	
Parameter	Mean ± Std	Mean ± Std	Significance
LF, ms^2	7.59 ±9.29	7.95 ±8.88	0,78
HF, ms^2	10.31 ±7.57	10.4 ±7.16	0,93
LF/HF	0.84 ±0.92	0.9 ±0.86	0,64
LF norm, *n.u*	36.77 ±19.86	40.15 ±18.21	0,21
HF norm, *n.u*	63.23 ±19.86	59.85 ±18.21	0,21

MI, *ms*	870.72 ±205.89	874.15 ±169	0,90
SD, *ms*	325.82 ±124.95	328.46 ±102.73	0,87
RMSD, *ms*	380.93 ±159.77	371.88 ±138.54	0,67
RR50, *%*	0.31 ±0.08	0.32 ±0.06	0,39

Tab 5.2 Changes in HRV parameters for AF.

After that, there were isolated cases with negligible duration of AF<5 sec. These cases could be considered "anomalies", that is the AF just happened there as an aberration. The hypothetical prediction would be that such cases differ very little from the cases when AF was not induced at all, and therefore the autonomic outlook in such cases of negligible AF would be similar to the cases with no AF.
But this hypotesis wasn't supported by the results below (Tab. 5.3).

DOGS ALL:Changes in HRV parameters for AF shorter than 5s and AF longer than 5s					
Duration AF	NO AF	AF < 5s		AF > 5s	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	7.59 ± 9.29	10.4 ± 10.63	0,34	7.5 ± 8.55	0,95
HF, ms^2	10.31 ± 7.57	8.37 ± 5.21	0,40	10.77 ± 7.43	0,68
LF/HF	0.84 ± 0.92	1.24 ± 1.08	0,17	0.84 ± 0.81	0,98
LF norm, *n.u*	36.77 ± 19.86	46.48 ± 21.39	0,12	39 ± 17.52	0,44
HF norm, *n.u*	63.23 ± 19.86	53.52 ± 21.39	0,12	61 ± 17.52	0,44
MI, *ms*	870.72 ± 205.89	850.41 ± 181.6	0,75	878.5 ± 167.85	0,79
SD, *ms*	325.82 ± 124.95	334.14 ± 116.03	0,83	327.42 ± 101.15	0,93
RMSD, *ms*	380.93 ± 159.77	374.12 ± 160.53	0,89	371.47 ± 135.66	0,68
RR50, *%*	0.31 ± 0.08	0.32 ± 0.06	0,78	0.32 ± 0.07	0,41

Tab 5.3 Changes in HRV parameters for AF shorter than 5s and AF longer than 5s

Because the previous analyses were not significant at all, the values for each group were compared with episodes where NO AF was detected to see some changes.

DOGS ALL:Changes in HRV parameters for AF of different duration					
Duration AF	NO AF	AF<10s		10s<AF<30s	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	7,59 ± 9,29	10,41 ± 10,48	0,27	6,22 ± 7,00	0,65
HF, ms^2	10,31 ± 7,57	8,26 ± 4,91	0,30	6,18 ± 5,85	0,09
LF/HF	0,84 ± 0,92	1,25 ± 1,01	0,10	1,39 ± 1,42	0,08
LF norm, *n.u*	36,77 ± 19,86	47,36 ± 20,48	**0,05**	49,90 ± 17,43	**0,04**
HF norm, *n.u*	63,23 ± 19,86	52,64 ± 20,48	**0,05**	50,10 ± 17,43	**0,04**
MI, *ms*	870,72 ± 205,89	870,56 ± 177,23	1,00	820,76 ± 145,94	0,45

SD, *ms*	325,82 ± 124,95	339,48 ± 109,79	0,68	270,61 ± 96,91	0,17
RMSD, *ms*	380,93 ± 159,77	378,11 ± 150,66	0,95	306,62 ± 109,45	0,15
RR50, *%*	0,31 ± 0,08	0,33 ± 0,07	0,39	0,31 ± 0,05	0,82
Duration AF		30s<AF<3min		AF>3min	
Parameter		Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2		4,74 ± 4,05	0,18	9,67 ± 10,63	0,30
HF, ms^2		11,56 ± 7,00	0,48	12,36 ± 8,08	0,20
LF/HF		0,53 ± 0,38	0,13	0,81 ± 0,63	0,83
LF norm, *n.u*		31,03 ± 15,04	0,21	39,26 ± 16,61	0,54
HF norm, *n.u*		68,97 ± 15,04	0,21	60,74 ± 16,61	0,54
MI, *ms*		867,84 ± 140,76	0,95	901,62 ± 194,15	0,47
SD, *ms*		322,11 ± 72,55	0,90	349,25 ± 116,30	0,37
RMSD, *ms*		365,63 ± 118,13	0,68	398,19 ± 153,73	0,60
RR50, *%*		0,32 ± 0,06	0,73	0,32 ± 0,07	0,49

Tab 5.4 Changes in HRV parameters for AF of different duration.

In the above mentioned table (Tab. 5.4), there is visible that two parameters are significant. There are LF norm and HF norm. The significance is 0,05 for episodes with AF shorter than 10s and 0,04 for episodes with AF between 10-30s. Not so high significance is also in cases of HF and LF/HF. In the statistic above, there can be observed same tendency of changes for the different AF duration.
HF decrease and LF/HF increase for the episodes with AF shorter than 30s. HF increase and LF/HF decrease in cases with AF longer than 30s. This is the reason why time AF 30s was chosen as a dividing parameter for the next analysis.

The changes of parameters are also visible from the following *boxplot* figures (Fig. 5.1 and 5.2). The colors are blue for outline, red for median line and black for whiskers.

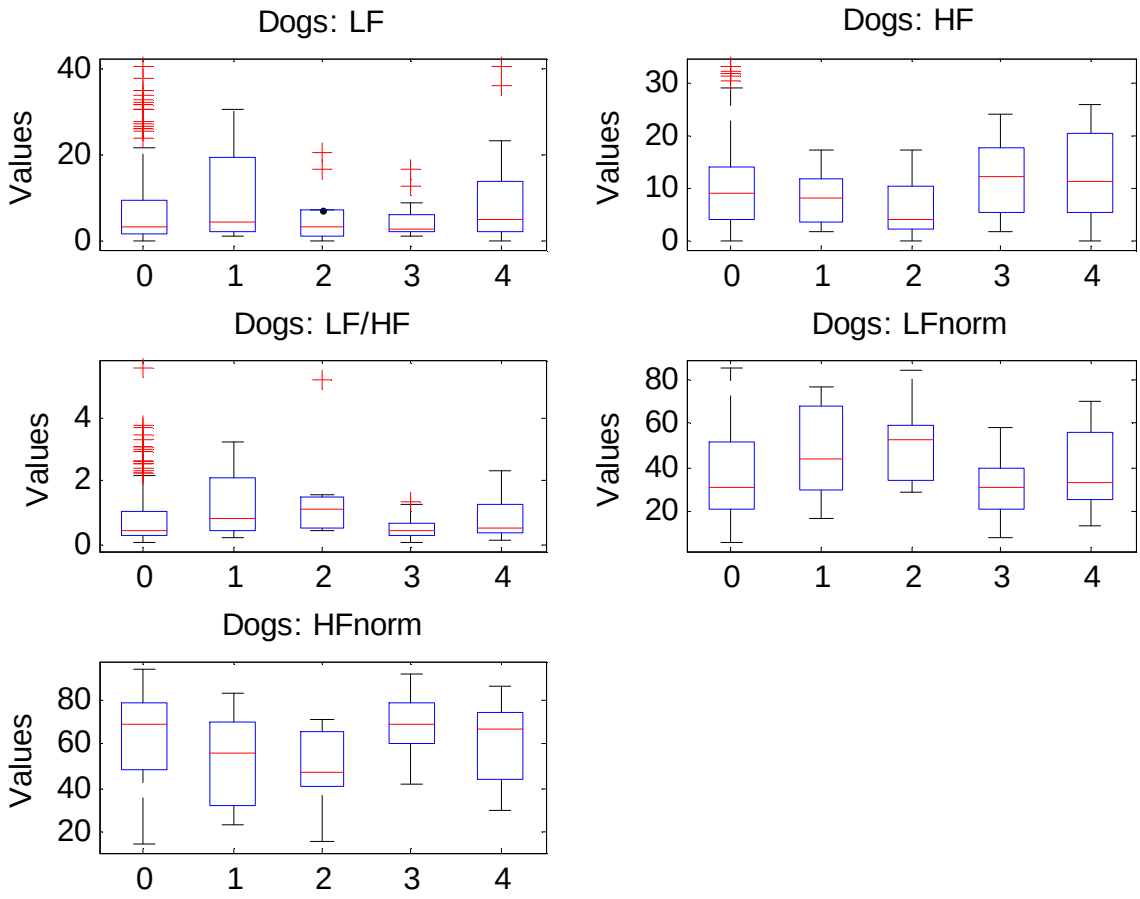

Fig 5.1 Frequency domain measures of HRV of episodes without the AF (0) and before the AF (1 – AF<10s; 2 – 10s<AF>30s; 3 – 30s<AF>3min; AF>3min) for dog number 6. LF, power in very low frequency range <= 0.04Hz in ms2; HF, power in high frequency range <= 0.15-0.4Hz in ms2; LF/HF, ratio LF [ms2]/HF [ms2].; LF norm, LF power in normalised units (n.u.), LF/(Total power-VLF)x100; HF norm, HF power in normalised units (n.u.), HF/(Total power-VLF)x100.

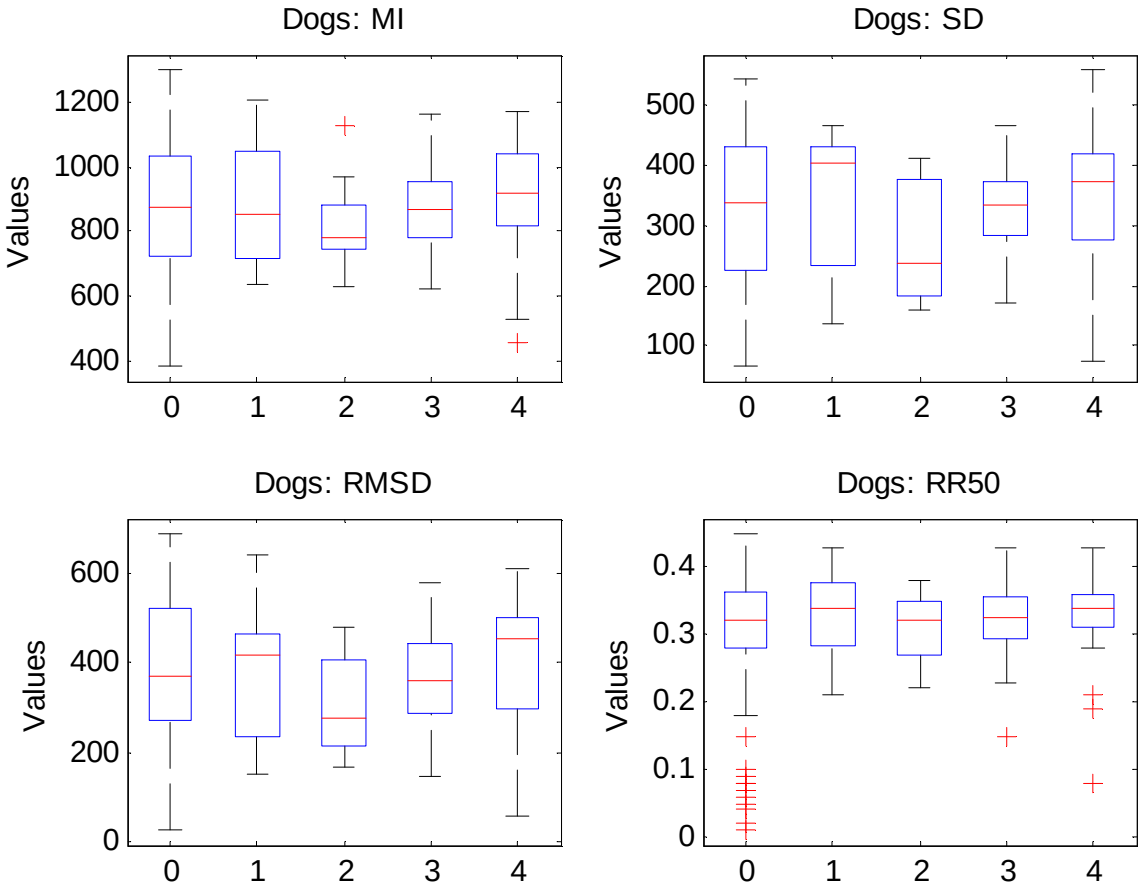

Fig 5.2 Time domain measures of HRV of episodes without the AF (0) and before the AF (1 – AF<10s; 2 – 10s<AF>30s; 3 – 30s<AF>3min; AF>3min) for dog number 6. MI, mean interval; SD, standard deviation; RMSSD, root mean square successive differences; RR50, the proportion of cycles during which the RR difference is > 50 ms.

Because of the previous analysis, in the following table (Tab. 5.5), there are observed the common differences and changes of the time and frequency domain parameters. The group of episodes with AF longer than 30s is compared with the rest of evaluated episodes

DOGS ALL:Changes in HRV parameters for AF longer than 30s			
Duration AF	NO AF&AF< 30s	AF> 30s	*Significance
Parameter	Mean ± Std	Mean ± Std	Significance
LF, ms^2	7.73 ± 9.28	7.52 ± 8.70	0,89
HF, ms^2	9.97 ± 7.38	12.01 ± 7.56	0,09
LF/HF	0.90 ± 0.96	0.68 ± 0.54	0,14
LF norm, *n.u*	38.15 ± 20.07	35.68 ± 16.30	0,44
HF norm, *n.u*	61.85 ± 20.07	64.32 ± 16.30	0,44
MI, *ms*	868.33 ± 201.13	886.93 ± 172.03	0,56
SD, *ms*	324.16 ± 122.94	337.45 ± 99.61	0,49
RMSD, *ms*	377.19 ± 157.35	384.03 ± 138.88	0,79
RR50, *%*	0.31 ± 0.08	0.32 ± 0.07	0,50

Tab 5.5 Changes in HRV parameters for AF longer than 30s

More significant results are form the next analyse, where episodes with no AF, AF shorter than 30s and AF longer than 30s are compared.

DOGS ALL:Changes in HRV parameters for short and long AF					
Duration AF	No AF	Short AF (AF<30s)		Long AF (AF>30s)	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	7,59 ± 9,29	8,73 ± 9,32	0,57	7,52 ± 8,70	0,96
HF, ms^2	10,31 ± 7,57	7,43 ± 5,29	0,07	12,01 ± 7,56	0,17
LF/HF	0,84 ± 0,92	1,31 ± 1,16	**0,02**	0,68 ± 0,54	0,26
LF norm, *n.u*	36,77 ± 19,86	48,38 ± 18,98	**0,01**	35,68 ± 16,30	0,73
HF norm, *n.u*	63,23 ± 19,86	51,62 ± 18,98	**0,01**	64,32 ± 16,30	0,73
MI, *ms*	870,72 ± 205,89	850,64 ± 164,10	0,64	886,93 ± 172,03	0,62
SD, *ms*	325,82 ± 124,95	311,93 ± 108,35	0,60	337,45 ± 99,61	0,56
RMSD, *ms*	380,93 ± 159,77	349,51 ± 137,88	0,35	384,03 ± 138,88	0,90
RR50, *%*	0,31 ± 0,08	0,32 ± 0,06	0,61	0,32 ± 0,07	0,47

Tab 5.6 Changes in HRV parameters for short and long AF

Some important changes were observed for the episodes with short AF (AF<30s). HF decreased from 10,31±7,57 ms2 to 7,43±5,29 ms2 with significance 0,0670; LF/HF increased from 0,84±0,92 to 1,31±1,16 with significance 0,0236. The significance 0,0063 was for changes of LF norm from 36,77±19,86 n.u to 48,38±18,98 n.u and for HF norm, which decreased from 63,23±19,86,n.u to 51,62±18,98n.u.

5.3 STABILITY AND TENDENCY RESULTS

DOGS ALL:Changes in HRV parameters for AF (2 x 5min)			
Part	part 1		
Duration AF	NO AF	AF	
Parameter	Mean ± Std	Mean ± Std	Significance
LF, ms^2	4.1 ± 5.21	4.03 ± 4.59	0,93
HF, ms^2	5.5 ± 4.36	5.5 ± 3.9	0,99
LF/HF	0.92 ± 1.06	0.96 ± 1.08	0,75
LF norm, *n.u*	37.61 ± 20.71	39.64 ± 20.44	0,48
HF norm, *n.u*	62.39 ± 20.71	60.36 ± 20.44	0,48
MI, *ms*	881.02 ± 219.83	872.93 ± 180.55	0,78
SD, *ms*	317.75 ± 130.88	324.5 ± 110.26	0,70
RMSD, *ms*	380.04 ± 171.46	377.55 ± 149.89	0,91
RR50, *%*	0.31 ± 0.09	0.33 ± 0.07	0,13
Part	part 2		
Duration AF	NO AF	AF	
Parameter	Mean ± Std	Mean ± Std	Significance
LF, ms^2	3.47 ± 4.4	3.99 ± 4.92	0,42
HF, ms^2	4.8 ± 3.58	4.97 ± 3.61	0,74
LF/HF	0.87 ± 0.99	0.94 ± 0.89	0,65
LF norm, *n.u*	36.93 ± 20.56	40.67 ± 18.86	0,18
HF norm, *n.u*	63.07 ± 20.56	59.33 ± 18.86	0,18
MI, *ms*	868.36 ± 206.16	885.68 ± 175.86	0,53
SD, *ms*	322.05 ± 129.29	319.21 ± 109.92	0,87
RMSD, *ms*	381.55 ± 163.9	366.9 ± 147.15	0,51
RR50, *%*	0.32 ± 0.09	0.32 ± 0.07	0,96

Tab 5.7 Changes in HRV parameters for AF (2 x 5min)

DOGS ALL:Changes in HRV parameters for AF shorter than 5s and AF longer than 5s (2 x 5min)					
Part	part 1				
Duration AF	NO AF	Short AF (AF<5s)		Long AF (AF>5s)	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	4.1 ± 5.21	6.77 ± 7.08	0,11	3.53 ± 3.86	0,44
HF, ms^2	5.5 ± 4.36	4.72 ± 2.58	0,56	5.64 ± 4.1	0,82
LF/HF	0.92 ± 1.06	1.36 ± 1.25	0,18	0.89 ± 1.04	0,87
LF norm, *n.u*	37.61 ± 20.71	47.29 ± 22.67	0,14	38.23 ± 19.89	0,84
HF norm, *n.u*	62.39 ± 20.71	52.71 ± 22.67	0,14	61.77 ± 19.89	0,84
MI, *ms*	881.02 ± 219.83	877.47 ± 187.32	0,96	872.09 ± 180.9	0,78
SD, *ms*	317.75 ± 130.88	354.38 ± 136.51	0,37	319.02 ± 105.21	0,95
RMSD, *ms*	380.04 ± 171.46	427.36 ± 181.25	0,38	368.42 ± 143.31	0,64
RR50, *%*	0.31 ± 0.09	0.34 ± 0.06	0,28	0.33 ± 0.08	0,22

Part	part 2				
Duration AF	NO AF	Short AF (AF<5s)		Long AF (AF>5s)	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	3.47 ± 4.4	3.68 ± 4.31	0,88	4.05 ± 5.06	0,40
HF, ms^2	4.8 ± 3.58	3.65 ± 3.04	0,30	5.21 ± 3.68	0,44
LF/HF	0.87 ± 0.99	1.14 ± 0.94	0,39	0.9 ± 0.88	0,86
LF norm, *n.u*	36.93 ± 20.56	46.19 ± 19.45	0,15	39.66 ± 18.74	0,36
HF norm, *n.u*	63.07 ± 20.56	53.81 ± 19.45	0,15	60.34 ± 18.74	0,36
MI, *ms*	868.36 ± 206.16	839.99 ± 194.55	0,66	894.06 ± 172.68	0,38
SD, *ms*	322.05 ± 129.29	300.58 ± 119.58	0,59	322.63 ± 108.78	0,98
RMSD, *ms*	381.55± 163.9	324.46 ± 170.28	0,26	374.68 ± 142.75	0,77
RR50, *%*	0.32 ± 0.09	0.31 ± 0.07	0,72	0.32 ± 0.07	0,84

Tab 5.8 Changes in HRV parameters for AF shorter than 5s and AF longer than 5s (2 x 5min)

DOGS ALL:Changes in HRV parameters for AF longer than 30s (2 x 5min)			
Part	part 1		
Duration AF	NO AF&AF<30s	AF>30s	
Parameter	Mean ± Std	Mean ± Std	*Significance
LF, ms^2	4.21 ± 5.26	3.5 ± 3.88	0,39
HF, ms^2	5.35 ± 4.25	6.17 ± 4.15	0,23
LF/HF	0.97 ± 1.12	0.75 ± 0.71	0,19
LF norm, *n.u*	38.75 ± 20.88	35.51 ± 19.35	0,33
HF norm, *n.u*	61.25 ± 20.88	64.49 ± 19.35	0,33
MI, *ms*	879.98 ± 214.3	873.28 ± 187.17	0,84
SD, *ms*	318.21 ± 129.91	326.07 ± 102.86	0,70
RMSD, *ms*	379.91 ± 169.36	376.81 ± 148.13	0,91
RR50, *%*	0.31 ± 0.08	0.33 ± 0.08	0,35
Part	part 2		
Duration AF	NO AF&AF<30s	AF>30s	
Parameter	Mean ± Std	Mean ± Std	*Significance
LF, ms^2	3.5 ± 4.39	4.14 ± 5.23	0,39
HF, ms^2	4.61 ± 3.51	5.95 ± 3.76	**0,02**
LF/HF	0.93 ± 1.02	0.72 ± 0.67	0,19
LF norm, *n.u*	38.43 ± 20.7	35.84 ± 17.37	0,43
HF norm, *n.u*	61.57 ± 20.7	64.16 ± 17.37	0,43
MI, *ms*	865.05 ± 202.31	910.19 ± 174.44	0,16
SD, *ms*	318.25 ± 127.21	335.01 ± 108.48	0,41
RMSD, *ms*	374.32 ± 162.96	391.95 ± 142	0,50
RR50, *%*	0.32 ± 0.09	0.32 ± 0.07	0,75

Tab 5.9 Changes in HRV parameters for AF longer than 30s (2 x 5min)

DOGS ALL:Changes in HRV parameters for short and long AF (2 x 5min)					
Part	part 1				
Duration AF	NO AF	Short AF (AF<30s)		Long AF (AF>30s)	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	4.1 ± 5.21	5.02 ± 5.63	0,41	3.5 ± 3.88	0,47
HF, ms^2	5.5 ± 4.36	4.27 ± 3.12	0,17	6.17 ± 4.15	0,34
LF/HF	0.92 ± 1.06	1.37 ± 1.48	**0,06**	0.75 ± 0.71	0,30
LF norm, *n.u*	37.61 ± 20.71	47.23 ± 20.59	**0,03**	35.51 ± 19.35	0,53
HF norm, *n.u*	62.39 ± 20.71	52.77 ± 20.59	**0,03**	64.49 ± 19.35	0,53
MI, *ms*	881.02 ± 219.83	872.28 ± 171.45	0,85	873.28 ± 187.17	0,83
SD, *ms*	317.75 ± 130.88	321.62 ± 124.93	0,89	326.07 ± 102.86	0,69
RMSD, *ms*	380.04±171.46	378.92 ±156.15	0,98	376.81 ± 148.13	0,91
RR50, *%*	0.31±0.09	0.33 ±0.07	0,24	0.33 ± 0.08	0,27
Part	part 2				
Duration AF	NO AF	Short AF (AF<30s)		Long AF (AF>30s)	
Parameter	Mean ± Std	Mean ± Std	Significance	Mean ± Std	Significance
LF, ms^2	3.47 ± 4.4	3.72 ± 4.38	0,79	4.14 ± 5.23	0,38
HF, ms^2	4.8 ± 3.58	3.16 ± 2.52	**0,03**	5.95 ± 3.76	**0,05**
LF/HF	0.87 ± 0.99	1.33 ± 1.1	**0,03**	0.72 ± 0.67	0,32
LF norm, *n.u*	36.93 ± 20.56	49.55 ± 18.57	**0,00**	35.84 ± 17.37	0,74
HF norm, *n.u*	63.07 ± 20.56	50.45 ± 18.57	**0,00**	64.16 ± 17.37	0,74
MI, *ms*	868.36 ± 206.16	840.58 ± 172.87	0,52	910.19 ± 174.44	0,21
SD, *ms*	322.05 ± 129.29	290.14 ± 108.7	0,24	335.01 ± 108.48	0,53
RMSD, *ms*	381.55± 163.9	320.82 ± 148.11	0,08	391.95± 142	0,69
RR50, *%*	0.32 ± 0.09	0.31 ± 0.08	0,77	0.32 ± 0.07	0,79

Tab 5.10 Changes in HRV parameters for short and long AF (2 x 5min)

6. DISCUSSION AND CONCLUSION

Heart rate (HR) is the net balance of opposite autonomic influences simultaneously interacting 19[3]. Sinus node behavior may not reliably reflect the status of autonomic activity at other levels in the heart; thus the effects of the autonomic nervous system on the sinoatrial node may be discrepant from that on the atrium, atrioventricular (AV) node, and ventricle. [3]. The neurogenic vagal and sympathetic drives can be visible from the HRV parameters. The functional responses to cholinergic stimulation occur within few ms, while those to adrenergic stimulation require seconds for target activation [3]. The previous studies in human models show that all conditions associated with an increase in sympathetic activity (head-up lilt test, standing, physical exercise, and mental stress) are characterized by an augmented LF and a diminished HF [3]. Although previous reports have found a more frequent incidence of vagally mediated AF in humans (4:1) (e.g., ocurents at night, at rest, during the postprandial state, and relaxed period that follow an exhertion, or after an emotion), the experience of other studies that the increase of neuronic adrenergic drive before AF is as frequent as the increase of parasympathetic drive [3]. Present study about paroxysmal atrial fibrillation (PAF) suggests that PAF episodes are preceded by fluctuations in autonomic tone, with a primary increase in adrenergic drive followed by a marked modulation toward vagal predominance. [13]

HRV is relatively new tool in the evaluation of sympathovagal balance [3]. But there are more new studies investigating the clinical value of HRV in cardiological diseases [4]. To the future there is tendency to develop numerically robust techniques suitable for fully autonomic measurement [4]. Different changes of HRV parameters were presented in the previous studies of AF. Changes in atria are observed to prevent disorders like AF.

In the analyses of this study were observed significant increase of LF/HF and LF norm and decrease HF and HFnorm for episodes, in which AF was shorter than 30s. It corresponds to the decrease of parasympathetic drive and the sympatovagal disbalance. In comparison, in episodes with AF longer than 30s there were observed the increase of HF and HFnorm and the decrease of LF/HF and LF. These changes

could be explained by the sympatovagal balance and by the increase of the vagal activity. The results for the AF longer than 30s were not significant. All there results were observed during 10 minutes preceding an episode AF. Next analysis for 2x5 minutes supported the tendency of significant changes of the 10 minutes test. The stability and reproducibility were also confirmed. These different results in two mentioned groups lead to hypotheses, that the occurrence of short and long AF has a different reason. Short episodes of AF could be generated when a certain disorder between sympathetic and parasympathetic tone is present. However in order to be able to generate longer AF episodes it is necessary another component not necessary related to the nervous system, it can be the effect of structural heart diseases. Is controversial, what is the shortest time of the changes in the ECG signal, which can be declared as an episode of AF, but this could be the question for the next studies.

For these analyses were used only six dogs` signals without any information about dogs and about the daily time. In the future studies could be distinguished episodes during the day from night episodes. To improve significance of these analyses more signals are necessary. In case of more signals with, AF can be divided in more time groups to look for the better dividing parameter than 30s. The other point could be the evaluation of more details about the type AF.

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