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HEART RATE VARIABILITY IN MEDICAL PRACTICE

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INTRODUCTION

Heart rate variability (HRV) is the spontaneous oscillation of beat-to-beat time intervals (expressed in ms) around the mean value (pulse in beats/m). It is mirroring the sympathetic-parasympathetic (vagal) balance. This makes it a valuable tool for investigation of the autonomic nervous system in almost all medical branches. HRV measurements are easy to perform, are noninvasive and have reliable reproducibility under standardized experimental conditions.

Many factors associated with sympathetic prevalence can decrease HRV: physical or mental stress, thyreotoxicosis, medications (including different kinds of doping) etc. HRV decrease also with increasing age, in diabetic patients due to diabetic cardiomiopathy, in hypertensive patients, acute myocardial infarction, severe brain damage, overtraining etc. So why, any time the sympathetic tone is find to be increased, it is accepted as an increase of health risk score.

PHYSIOLOGICAL BASIS OF HRV

The physiological basis of HRV are the fluctuations of the activity in brain cardiovascular vasoconstrictory and vasodilatatory centers. Normally these fluctuations are a result of blood pressure oscillation (baroreflex modulated); respiration (parasympathetically mediated via thoracic stretch receptors); thermoregulation (sympathetically mediated via thermoregulatory peripheral blood flow adjustments) and circadian biorhythm. All these factors can influence the length of beat-to-beat intervals, named cardiointervals or R-R intervals. Their values are the object of mathematical estimation yelding the amount of HRV.

As the increase or the decrease of HRV are reflected by both: the difference of the length of cardiointervals (expressed with a time based measurements as ms), and the difference of the spectral power (expressed with a frequency based measurement as Hz), there exists two types of HRV measures:

a) time-domain based HRV measures

The time domain indexes are relatively easy to calculate and can be devided to two classes: the first is based on the differences between every cardiointerval and their mean value. This is cardiointervals standard deviation (SD); the second is based on the differences between every cardiointerval and the next one ( ) (1). Both are named "short term variability" (STV). Long term variability (LTV) indexes are the same, but based on the means of every five successive cardiointervals (from every five, one cardiointervals is produced). There are many others time-domain based indexes which are included in the mathematical algorythms for assessment of the medical phenomena being studied (2, 3). These indexes are highly correlating with STV and LTV.

b) frequency-domain based HRV measures

The submission of cardiointervals to frequency-domain based analysis requires fast Fourier-transform in order to obtain their power density spectrum. It yelds information about the amount of variance connected with oscillations of heart rate at various spectral frequencies and is measured in milliseconds squared (ms2). As the spectral power associated with the long spectral waves (0.01 - 0.05 Hz, thermoregulation) is namely sympathetically modulated, and the spectral power associated with the short spectral waves (0.2 - 0.4 Hz, respiration) is namely parasympathetically modulated, their ratio is used for description of the autonomic balance. Middle spectral waves (0.06 - 0.16 Hz, blood pressure are less informative. Frequency-domain based indexes can be also used for assessment of "mental stress", because this type of stress is activating the higher levels of the cardiovascular regulation centers (cortical), producing variability in the area of the long spectral waves. For this assessment some distinguishing with thermoregulatory, peripheral vasomotor or renin-angiotensin contribution is provided.

MEASUREMENT OF HRV

Ordinary HRV measures are obtained from a 10 minute sequence of cardiointervals.

Cardiointervals can be elected from: ECG, plethysmogram, phonocardiogram, but predominantly ECG signal is used.

HRV IN DIFFERENT MEDICAL AREAS

a) Cardiology and cardiovascular diseases

A reduction of vagal tone is found to be associated with acute myocardial infarction (so HRV can be used as a prognostic tool in postinfarktion period). HRV has a high association with the risk for sudden cardiac death, and arrhythmic complications (4). Diminished vagal activity is found in patients with coronary artery disease and essential hypertension. After heart transplantation the allograft rejection can be predicted by decreased total spectral power.

b) Neurology

HRV reflects autonomic dysfunction of central origin in patients with parkinsonism, spinocerebellar degeneration, Shy - Drager syndrome, multiple sclerosis, chronic alcoholism, Guillan - Barre syndrome, quadriplegia etc.

c) Diabetes mellitus

Diabetic cardiomiopathy is marcably decreasing HRV. As this decrease is ofently preceding clinical symptoms, HRV can be used for early prediction of the diabetic pathology (5), especially in children.

d) Glomerulonephrites with renal insufficiency

Decrease of vagal tone was found in uremic patients, revealed namely by the diminution of the short waves-associated spectral power.

e) Pharmacological influence

Calcium channel blockers (as atenolol f.e.), beta-blockers (as diltiazem f.e.), tranquilisers, relaxants, scopolamine (vagomimetic), etc. are increasing the time as well as the frequency-domain HRV measures. Contrary, atropine is decreasing vagal activity (2). It is interesting to note, that nifidipine (Ca-blocker) has not effect upon HRV.

f) Toxicology

HRV analysis can reveal the severity of autonomic dysfunction caused by environmental neurotoxic agents as organic solvents, pesticides, nitrates, organophosfates, leads etc.

g) Work-lelated stress

Vibratory tool operations, inconvenient regimes of work and rest, dust of different kinds, ergonomical disadvantages, overload, bad psychological microclimate etc. can decrease HRV. This is used for their quantitative assessment and control (3).

h) Medical ecology

Ecological hazard needs to be evaluated not only by measuring of the level of ecological noxes, but also by the impact they have upon common functional status of the population living in ecologically contaminated areas. This can be done, before all, by following up the chronically increased sympathetical tone by HRV measurements.

i) Sport

The status of overtraining as well as the effect of relaxation procedures and the use of forbidden medicaments (doping) can be successfully controlled by HRV.

j) Applied psychology

By multiple step regression analysis is found that phenomena as depression, burnout, lack of social support, uncontrolled locus of control, bad family or social relations etc. are increasing the long waves spectral power and decreasing the total spectral power.

k) Unconventional medical treatments

The effect of manual therapy, traditional chinese therapies, aromatherapy, massages, sauna, autogene training, yoga, Silva method etc. is difficult to be assessed without following their impact upon common functional status, which is reflected by HRV.

l) Transport, army and cosmic medicine

All these professions or activities presuppose a high level of health reserves and adaptation capacities. It was found, that the physical as well as the mental effort (6) required in these cases can be reliably evaluated by HRV measurement.

m) Health (life) insurance

Recently some attempts to use HRV as a predictor of overall health risk (as a factor influencing insurance conditions) are done in Norway and Japan.

COMERCIALLY AVAILABLE HRV EQUIPMENT

As the use of HRV analysis increases, the need for commercially available HRV equipment is also increasing. The conventional Holter monitors are not convenient for HRV measurements because of variations in tape speed. Modern ECG apparatuses include STV, LTV and spectral analyses, but they are expensive and the obtained measures are not sufficient. Some specialized hard and software HRV equipment’s are also very expensive and posses too narrow professional destination. From another side all these apparatuses are not supplied with a reliable correction for artificially short or long R-R intervals and algorithm for extrasystoles recognition. These disadvantages are removed by the

created in National Center of Hygiene Medical Ecology and Nutrition "Danev tests" (DaTe).

DATE are 3 tests based on HRV analysis: 1. assessment of stress and pathological changes of heart rhythm; 2. assessment of physical fitness; 3. assessment of health risk (%). The last tests is based on the results obtained by the first two tests.

DATE are developed in the last 7-8 years on the basis of thousands investigated by HRV persons.

n) The advantage of DATE

a) DaTe software

- assessment not only of STV, LTV and frequency-based HRV measures, but also of the physical and mental stress. This is possible due to the implementation of a new statistical approach named "singular value decomposition" performed in the space of Karunen-Loew, which yields information about the main HRV components accompanying these phenomena.
- assessment of the normality of cardiac rhythm (number of ventricular premature heart beats)
- assessment of physical fitness (training) by a testing procedure including repeated postural changes form siting to standing up five times consecutively.
- assessment of functional age and vitality level.
- assessment of HRV based health risk (%). This method proved to be very reliable (3, 7).
- establishing of age-related bioconstant values for all HRV measures.
- perfect modern realization of both: DOS and Windows DATE versions.
- possibility to be adjusted to the specific demands of the separate medical problems.
- easy to be learned without special medical or computer education.

b) DaTe hardware

-DATE specialized devices for conversion of ECG signal to cardiointervals are produced in Denmark or Norway in accordance with EC requirements.

- electronically simple and very reliable construction being long time in use without serious defects.
- two types of hardware being available: first, working simultaneously with PC (IBM compatible) and second, working separately with possibility to transmit accepted data to PC on line or latter.
- electromagnetic and humidity isolation.
- low price and 2 years warranty.

<u>Where Danev tests were used</u>

Danev tests were used successfully in:

- work physiology for assessment of work-related health risk, overfatigue; shift work load; specific demands posed by different kinds of industrial production (electrical-power stations; TV retranslating stations; still, cooper, silver and gold productions; agriculture; cotton production; chemical plants etc.
- children hygiene for prediction of diabetes and essential hypertension
- sport: heavy lifting, box, athletics alpinismus

- surgery to control the operation stress
- air and sea forces in hypobaric or hyperbaric cameras
- transport medicine in personal of electric trains
- chip building industry (noise and vibration).
- alternative medicine for controlling it's effect.

As Danev tests are used also in Norway, Denmark, Germany, Japan and USA, their advantages were confirmed by the work in many scientific and applied medical directions.

CONCLUSION

Medical or related specialists needs easy and reliably methods for quantitative evaluation of autonomic tone, because it is the main moderator of health and illness (7). HRV analysis is providing such a possibility. HRV based Danev tests proved to be a convenient tool for this purpose, aimed to help all medical branches where sympathetical-to-parasympathetical balance have to be controlled.

Fig 1 gives example of time-domain and frequency domain based HRV indexes obtained by DATE in: A-parasympathetic prevalence and B-sympathetic prevalence.

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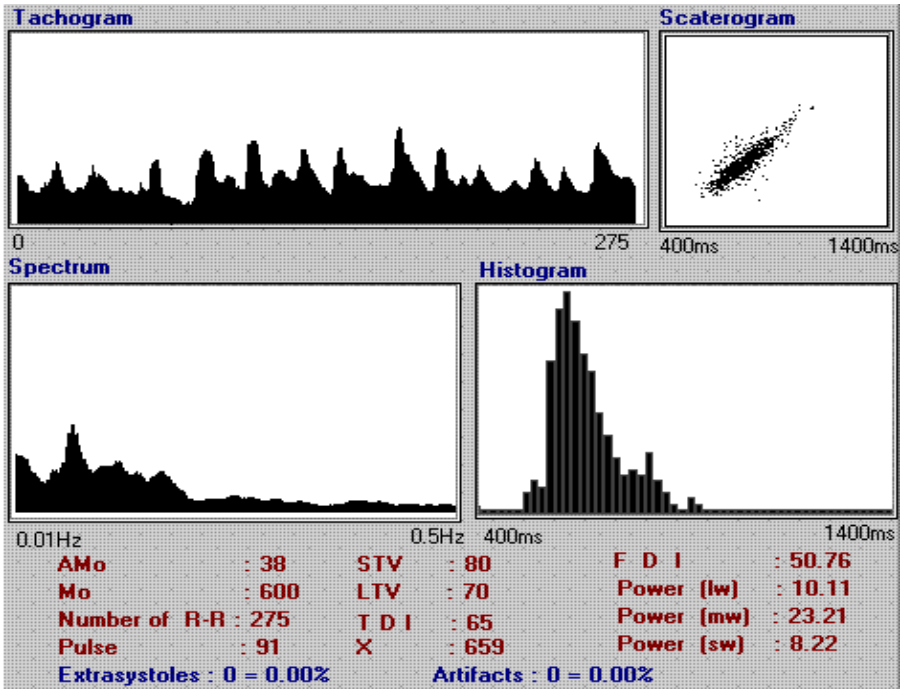
Fig. 1. Main DaTe measures in: A. Parasympathetic and B. Sympathetic prevalence.

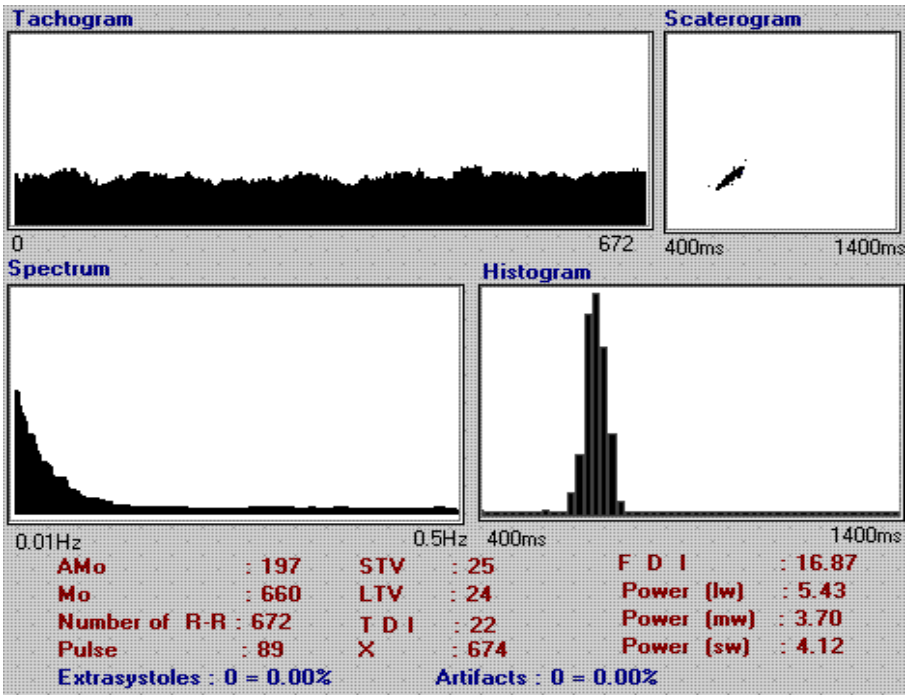
Danev Tests

A.



Physical Stress = 144 Mental Stress = 194

B.



Physical Stress = -233 Mental Stress = -156