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Basic notions of heart rate variability and its clinical applicability

Noções básicas de variabilidade da frequência cardíaca e sua aplicabilidade clínica

Luiz Carlos Marques VANDERLEI[1], Carlos Marcelo PASTRE[1], Rosângela Akemi HOSHI[2], Tatiana Dias de CARVALHO[2], Moacir Fernandes de GODOY[3]

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Abstract

Autonomic nervous system (ANS) plays an important role in the regulation of the physiological processes of the human organism during normal and pathological conditions. Among the techniques used in its evaluation, the heart rate variability (HRV) has arising as a simple and non-invasive measure of the autonomic impulses, representing one of the most promising quantitative markers of the autonomic balance. The HRV describes the oscillations in the interval between consecutive heart beats (RR interval), as well as the oscillations between consecutive instantaneous heart rates. It is a measure that can be used to assess the ANS modulation under physiological conditions, such as wakefulness and sleep conditions, different body positions, physical training and also pathological conditions. Changes in the HRV patterns provide a sensible and advanced indicator of health involvements. Higher HRV is a signal of good adaptation and characterizes a health person with efficient autonomic mechanisms, while lower HRV is frequently an indicator of abnormal and insufficient adaptation of the ANS, provoking poor patient's physiological function. Because of its importance as a marker that reflects the autonomic nervous system activity on the sinus node and as a clinical instrument to assess and identify health involvements, this study reviews conceptual aspects of the HRV, measurement devices, filtering methods, indexes used in the HRV analyses, limitations in the use and clinical applications of the HRV.

Descriptors: **Autonomic nervous system. Heart rate. Parasympathetic nervous system. Sympathetic nervous system.**

Resumo

O sistema nervoso autônomo (SNA) desempenha um papel importante na regulação dos processos fisiológicos do organismo humano tanto em condições normais quanto patológicas. Dentre as técnicas utilizadas para sua avaliação, a variabilidade da frequência cardíaca (VFC) tem emergido como uma medida simples e não-invasiva dos impulsos autonômicos, representando um dos mais promissores marcadores quantitativos do balanço autonômico. A VFC descreve as oscilações no intervalo entre batimentos cardíacos consecutivos (intervalos R-R), assim como oscilações entre frequências cardíacas instantâneas consecutivas. Trata-se de uma medida que pode ser utilizada para avaliar a modulação do SNA sob condições fisiológicas, tais como em situações de vigília e sono, diferentes posições do corpo, treinamento físico, e também em condições patológicas. Mudanças nos padrões da VFC fornecem um indicador sensível e antecipado de comprometimentos na

1. PhD, Assistant Professor at the Faculty of Health and Technology – FCT/UNESP – Presidente Prudente – São Paulo, Physiotherapy Department.
2. Graduation in Physiotherapy; Master's Degree Student of the Stricto Sensu Postgraduation Course in Physiotherapy - Faculty of Health and Technology – FCT/UNESP – Presidente Prudente – São Paulo, Physiotherapy Department.
3. Full Professor of the São José do Rio Preto Medical School – FAMERP – São José do Rio Preto – São Paulo, Cardiology and Cardiovascular Surgery Department.

This study was carried out at the Faculty of Health and Technology – FCT/UNESP – Presidente Prudente – São Paulo, SP, Brazil and São José do Rio Preto Medical School – FAMERP – São José do Rio Preto, SP, Brazil.

Correspondence address:
Luiz Carlos Marques Vanderlei. Rua Bela Vista, 822 - Cidade Jardim - Presidente Prudente, SP, Brazil. CEP 19023-440.
E-mail: vanderle@fct.unesp.br

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saúde. Uma alta variabilidade na frequência cardíaca é sinal de boa adaptação, caracterizando um indivíduo saudável, com mecanismos autonômicos eficientes, enquanto que, baixa variabilidade é frequentemente um indicador de adaptação anormal e insuficiente do SNA, implicando a presença de mau funcionamento fisiológico no indivíduo. Diante da sua importância como um marcador que reflete a atividade do SNA sobre o nódulo sinusal e como uma ferramenta clínica para avaliar e identificar comprometimentos na saúde, este artigo revisa aspectos conceituais da VFC, dispositivos de mensuração, métodos de filtragem, índices utilizados para análise da VFC, limitações de utilização e aplicações clínicas da VFC.

Descritores: **Sistema nervoso autônomo. Frequência cardíaca. Sistema nervoso parassimpático. Sistema nervoso simpático.**

INTRODUCTION

The control of the cardiovascular system is accomplished in part by the autonomic nervous system (ANS), which provides afferent and efferent nerves to the heart, in the form of sympathetic terminations throughout the myocardium and parasympathetic to the sinus node, atrial myocardium and atrioventricular node [1].

The influence of the ANS on the heart is dependent on informations from baroreceptors, chemoreceptors, atrial receptors, ventricular receptors, changes on the respiratory system, vasomotor system, the renin-angiotensin-aldosterone system and the thermoregulatory system, among others [2,3].

This neural control is closely linked to heart rate (HR) and baroreceptor reflex activity [1]. From the afferent informations, by means of a complex interaction between stimulation and inhibition, the responses from sympathetic and parasympathetic pathways are formulated and modify the HR, by adapting to the needs of each moment.

The increase in HR is consequence of increased action of the sympathetic pathway and reduced parasympathetic activity, or that is, vagal inhibition, whereas its reduction depends mainly on the predominance of vagal activity [1,4,5].

The heart is not a metronome and its beats do not have the regularity of a clock, so changes in HR, defined as heart rate variability (HRV), are normal and expected and indicate the heart's ability to respond to multiple physiological and environment stimuli, among them, breathing, physical exercise, mental stress, hemodynamic and metabolic changes, sleep and orthostatism, as well as to compensate disorders induced by diseases [1,4,6-8].

In general, HRV describes the oscillation of the intervals between consecutive heart beats (RR intervals), which are related to the influences of the ANS on the sinus node, being a noninvasive measurement that can be used to identify phenomena related to the ANS in healthy individuals, athletes and patients with diseases [1,9,10]. Figure 1 shows rate tachogram obtained from the RR intervals of a normal young adult and a normal newborn. It is observed that the HRV is much smaller in the newborn.

HRV has been studied for several years, with an increasing interest in understanding its mechanisms and its clinical utility in diseases. Historically, its clinical interest emerged in 1965 when Hon and Lee showed a well-defined clinical application of HRV in the monitoring area of fetal distress. In 1977, Wolf et al. showed an association between decreased HRV and increased risk of mortality after acute myocardial infarction, and Kleiger et al. in 1987, confirmed that HRV was a powerful and independent predictor of mortality after acute myocardial infarction [11].

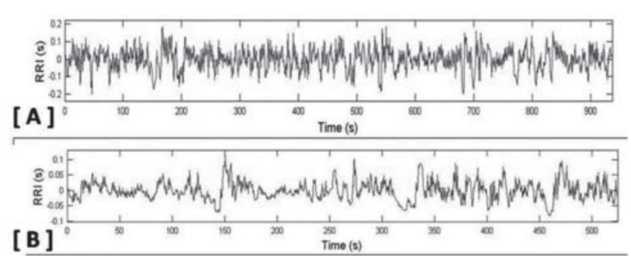


Fig. 1 - Tachogram of a normal young adult (A) and a normal newborn (B). The heart rate variability in panel B is much smaller than in panel A.

Changes in patterns of HRV provides a sensitive and early indicator of health impairments. High HRV is a sign of good adaptation, by characterizing a healthy individual with efficient autonomic mechanisms. Conversely, low HRV is often an indicator of abnormal and inadequate adaptation of the ANS, which may indicate the presence of physiological malfunction in the patient, requiring further investigations in order to find a specific diagnosis [10].

The wide possibility of use and ease of data acquisition characterize this resource. One should also highlight that the disclosure of current information regarding the HRV, such as concepts, analysis models, forms of interpreting results and clinical applicability, is an aid to both researchers and clinicians who work in various areas of health. Thus, in order to insert elements in the literature relating to an easy-to-use, comprehensive and non-invasive technique, it was considered appropriate to undertake research on the subject.

MEASUREMENT DEVICES

The cardiac excitation begins with an impulse generated in the sinus node, which is distributed through the atria, resulting in atrial depolarization, which is represented on the electrocardiogram (ECG) by the P wave. This impulse is conducted to the ventricles through the atrioventricular node and distributed by the Purkinje fibers, resulting in depolarization of the ventricles, which is represented on the ECG by the Q, R and S waves, forming the QRS complex. Ventricular repolarization is represented by the T wave [12]. The HRV indexes are obtained by analyzing the intervals between R waves, which can be captured by instruments such as electrocardiographer, digital-to-analog converter and the cardio-frequency meter, from external sensors placed at specific points of the body [1,4].

One of the digital-to-analog converter available is the Powerlab, an instrument used for biosignal multimodal monitoring, considered the gold standard for high-fidelity ECG measuring, whose signals captured are transferred to a computer, saved and analyzed after filtering [13].

The ECG and analog-to-digital converter used for HRV analysis, make difficult the applicability in situations outside the laboratory environment, such as on physical training conditions, in addition to present a high cost [14-16].

The cardio-frequency meters have solved these problems, since such devices are more accessible both in respect to cost and practicality [17]. A model with such characteristics is the frequency meter Polar S810 that, according Kingsley et al. [15], showed good accuracy in the records in low-intensity exercise, when compared to the outpatient electrocardiogram, which was also observed by Gamelin et al. [14] in a study comparing the data obtained by ECG and the Polar S810, both in situations of exercise and rest.

In this device, a belt with electrodes positioned in the chest of the patient, captures the heart's electrical impulses and transmits them through an electromagnetic field to the monitor. The signal captured is sent by an interface to the Polar Precision Performance software. In this equipment, the units of time are fixed at 1ms and the samples of RR intervals are collected at a frequency of 1000 Hz [1,18-21].

FILTERING METHODS

The presence of premature ectopic beats or artifacts interfere with the analysis of HRV, compromising the reliability of the indexes obtained, if they were not removed [21-23]. Filtering methods are able to detect abnormal RR intervals and correct them [24].

Most of the texts selected for the preparation of this manuscript does not approach detaily the procedures adopted for filtering. However, despite the lack of information, some authors describe the methodology used.

In the study of Thuraisingham [22], the method adopted to remove the artifacts was a impulse rejection filter that was effective for this purpose. Godoy et al. [23] used the Polar S810 for the collection of RR intervals and performed filtering in two stages, one digital by means of the equipment's software and other manual, characterized by visual inspection of the RR intervals and excluding abnormal intervals. In this study, only series with more than 95% of sinus beats were included.

INDEXES OF HEART RATE VARIABILITY

For the HRV analysis, indexes obtained by linear methods, time and frequency domain, and nonlinear methods can be used [1].

Linear Methods

The linear methods are divided into two types: time domain analysis, performed by statistical and geometric indexes, and frequency domain analysis.

For the HRV time domain analysis, thus named for expressing the results in unit time (milliseconds), every normal RR intervals (sinus beats) is measured during a determined time interval and, thereafter, based on statistical or geometric methods (mean, standard deviation and histogram-derived indexes or the Cartesian coordinates map of the RR intervals), it is calculated the translator indexes of fluctuations during the cardiac cycles [9.25].

The statistical indexes in the time domain, obtained by the determination of the RR intervals corresponding to any point in time, are [1,10,26-29]:

a) SDNN - Standard deviation of all normal RR intervals recorded in a time interval, expressed in ms;

b) SDANN – Represents the standard deviation of the normal RR intervals means, every 5 minutes in a time interval, expressed in ms;

c) SDNNi – It is the mean of the standard deviation of normal RR intervals every 5 minutes, expressed in ms;

d) rMSSD - is the root-mean square of differences between adjacent normal RR intervals in a time interval, expressed in ms;

e) pNN50 - Represents the percentage of adjacent RR intervals with a difference of duration greater than 50ms.

The SDNN, SDANN and SDNNi are obtained from long-term records and represent the sympathetic and parasympathetic activity, but they do not allow to distinguish when changes in HRV are due to increased sympathetic tone or the withdrawal of vagal tone [28.29]. The rMSSD and pNN50 indexes represent the parasympathetic activity [1,10,26,27] as they are found from the analysis of adjacent RR intervals [25].

Another possibility to process RR intervals in time domain is from geometrical methods, whereas the triangular index and Lorenz plot (or Poincaré Plot) are the most known. The geometric methods present RR intervals in geometric patterns and several approaches are used to derive measures of HRV from them [1,4].

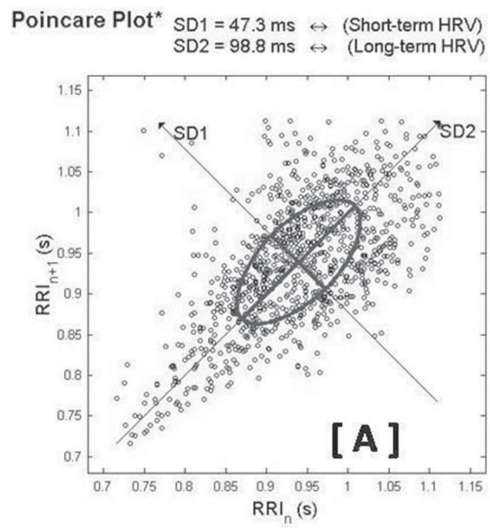
The triangular index is calculated based on the construction of a density histogram of normal RR intervals, which shows on the horizontal axis (x axis), the length of RR intervals and the vertical axis (y axis), the frequency on which each interval occurred. The junction of the points of the histogram columns forms a triangle-shaped figure and the width of the base of the triangle expresses the variability of RR intervals. The triangular index (corresponding to the base of the triangle) can be calculated by dividing the area (corresponding to the total number of RR intervals used to construct the figure) and height (corresponding to the number of RR intervals with modal frequency) of the triangle [4, 25,30].

This index has a close correlation with the standard deviation of all RR intervals and does not suffer the influence of ectopic beats and artifacts, as these are located outside the triangle [4].

The Poincaré plot is a geometric method for dynamic analysis of HRV, which represents a temporal series within a Cartesian plane in which each RR interval is correlated with the preceding interval and define a point in the plot [17,31-34]. Figure 2 shows the Poincaré plot of a normal young adult and a normal newborn.

The analysis of Poincaré plot can be performed in a qualitative manner (visual), by assessing the figure formed by its attractor, which is useful for showing the degree of complexity of RR intervals [35], or quantitative, by adjusting the ellipse of the figure formed by the attractor, from which three indexes can be obtained: SD1, SD2 and SD1/SD2 ratio [17].

SD1 represents the dispersion of points perpendicular to the line of identity and it seems to be an index of instantaneous recording of beat-to-beat variability; the SD2 represents the dispersion of points along the line of identity and represents the HRV in long-term records; the relationship of both (SD1/SD2) shows the ratio between the short- and long-term variations of the RR intervals [4.14].



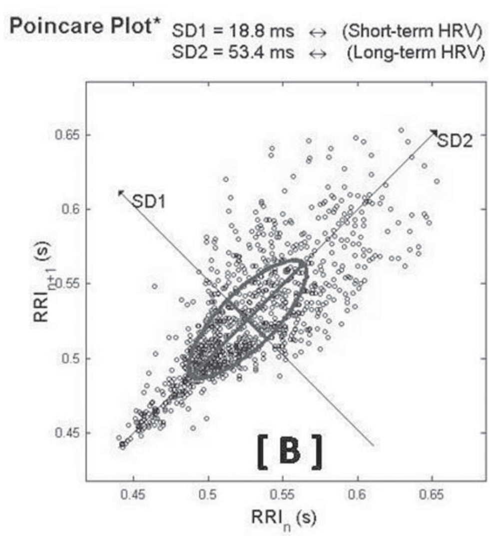


Fig. 2 – Poincaré chart of a normal young adult (A) and a normal newborn (B). The dispersion of both short- (SD1) and long-term in panel B (SD2) is smaller than in panel A

The qualitative analysis (visual) of the Poincaré plot is performed through the analysis of the figures formed by the plot attractor, which were described by Tulppo et al. [36] who classified them as follows:

1) Comet-shaped figure, on which an increase in the dispersion of beat-to-beat RR intervals is observed with increase in RR intervals, characteristic of a normal plot;

2) Torpedo-shaped figure, with a small global beat-to-beat dispersion (SD1) and without increasing the long-term dispersion of RR intervals;

3) Complex or parabolic figure, on which two or more distinct ends are separated from the main body of the plot, with at least three points included in each end.

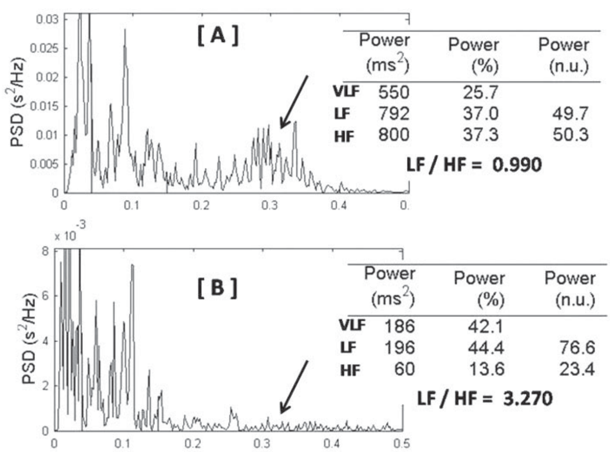


Fig. 3 - Spectral analysis of frequencies (Fast Fourier Transform) of a normal young adult (A) and a normal newborn (B). The high frequency (HF) component is proportionally smaller in the newborn (arrows) as well as the total power

Another linear method is the frequency domain, whereas the spectral power density is the most widely used, when it deals with studies with individuals at rest [17]. Examples of the frequency domain analysis can be seen in Figure 3.

This analysis decomposes the HRV in fundamental oscillatory components, whereas the main ones are [4,7,23,29,37-42]:

a) High-frequency component (*High Frequency* - HF), ranging from 0.15 to 0.4 Hz, which corresponds to the respiratory modulation and is an indicator of the performance of the vagus nerve on the heart;

b) Low frequency component (*Low Frequency* - LF), ranging between 0.04 and 0.15 Hz, which is due to the joint action of the vagal and sympathetic components on the heart, with a predominance of the sympathetic ones;

c) Components of very low frequency (*Very Low Frequency* - VLF) and ultra-low frequency (*Ultra Low Frequency* - ULF) - Indexes less used whose physiological explanation is not well established and seems to be related to the renin-angiotensin-aldosterone system, thermoregulation and the peripheral vasomotor tone [23.29].

The LF/HF ratio reflects the absolute and relative changes between the sympathetic and parasympathetic components of the ANS, by characterizing the sympathetic-vagal balance on heart [29].

To obtain the spectral indexes, the frequency tachogram undergoes mathematical processing, generating a tachogram, graph that expresses the variation of RR intervals as a function of time. The tachogram contains a signal apparently periodic that varies in time and is processed by mathematical algorithms, such as Fast Fourier Transform (FFT) or autoregressive models (AR) [1].

The FFT method is used to obtain an estimate of power spectral HRV during stationary studies. It also allows that the tachogram signal be recovered even after processing by the FFT, which demonstrates the objectivity of the technique, since informations are not lost during the process. The ease of application of this method and good layout are the main reasons for its widespread use [1].

In the AR model, the parameters estimation can be performed easily by solving linear equations. Thus, the spectral components can be distinguished regardless of preset frequency bands and power contained in the peaks can be calculated without the need of predefined spectral bands [1.43].

Normalizing data of the spectral analysis can be used to minimize the effects of changes in the VLF band. This is determined by dividing the power of a given component (LF or HF) by the total power spectrum, minus the VLF component and multiplied by 100 [9,44,45].

For analysis of the HRV indexes using linear and multiple methods, softwares can be used, among them the HRV analysis software [28], which can be downloaded free over the Internet.

Nonlinear methods

The nonlinear behavior is predominant in human systems, because of its dynamic nature complex, which can not be described properly by linear methods. Chaos theory describes elements manifesting behaviors that are extremely sensitive to initial conditions, and they are difficult to repeat, but nonetheless are deterministic elements [23].

The theories of nonlinear systems have been progressively applied to interpret, explain and predict the behavior of biological phenomena. These parameters have proved to be good predictors of morbidity and mortality in the clinical sphere, despite the need for scientific deepening, with expressive samples and prolonged follow-up. Such studies may be useful in research and treatment of heart disease [23].

Among the nonlinear methods used for HRV analysis, we can mention: detrended fluctuation analysis, correlation function, Hurst exponent, fractal dimension and Lyapunov exponent [4,23,29].

The records for analysis of HRV indexes by linear methods can be obtained in short periods (2, 5, 15 minutes) or long periods (24 hours), which is more common in clinical practice [25], whereas a minimum of 256 RR intervals is recommended for this analysis [7,9]. Seiler et al. [18], Brown & Brown [46] and Parekh & Lee [47] in their experiments for analysis of linear indexes, dismissed the initial periods of capture, on which many oscillations occur and the system is not in a stability state.

For analysis of the indexes in the chaos domain, a larger number of RR intervals is recommended. Godoy et al. [23] used a quantity of 1000 consecutive RR intervals for analysis.

LIMITATIONS ON USE

In addition to factors such as ectopic beats and artifacts [22], other conditions such as heart transplants, presence of arrhythmias and pacemakers produce inappropriate RR intervals to assess HRV, by limiting the use of this tool under these conditions. In transplant patients, control of the denervated heart is performed based on the venous return, atrial receptor stimulation, atrial stretch and hormones and other substances in the circulatory system [48-51], suggesting that HRV analysis does not represent the modulation of the heart by the ANS.

Artificial cardiac pacemakers are electronic devices of multiprogrammable stimulation that can replace electrical impulses and/or ectopic rhythms, to obtain the cardiac electrical activity as physiological as possible [52]. Since patients with pacemakers may have their heart rate modulated by such equipments, the analysis of HRV will not also reflect the autonomic modulation of the heart, limiting its use under this condition.

Condition also restricted the analysis of HRV is the presence of atrioventricular block because the impulse is not conducted properly to the ventricle, avoiding an analysis of RR intervals [53].

CLINICAL APPLICATIONS

Currently, the HRV indexes have been used to understand various conditions, such as coronary artery disease [54-57], cardiomyopathy [26.58], arterial hypertension [29,59-61], myocardial infarction [62-64], sudden death [65], chronic obstructive pulmonary disease [2,66,67], renal failure [68], heart failure [69], diabetes [70], stroke [71], Alzheimer's disease [72] leukemia [73], obstructive sleep apnea [74], epilepsy [75], headache [76], among others.

A reduced HRV has been identified as a strong indicator of risk related to adverse events in healthy individuals and patients with a large number of diseases, reflecting the vital role that ANS plays in maintaining health [10].

In diseases such as hypertension [29,59-61], acute myocardial infarction, coronary artery disease [29] and atherosclerosis [56], HRV indexes are reduced. Menezes Jr et al. [60] found reduced HRV in hypertensive compared to normotensive patients, when analyzing the SDNN, RMSSD, pNN50, HF, LF, LF/HF, probably due to a sympathetic hyperactivity. Decreased post-AMI HRV was also reported by several studies, as presented by Pecyna [63] in a review article.

In hypertrophic cardiomyopathy, it is assumed that the neuronal uptake of norepinephrine is impaired due to a decrease in the density of beta receptors [26]. Studies using HRV indexes in cardiovascular diseases can be seen in Table 1.

The assessment of HRV has also been widely used in order to diagnose both physiological and psychological disorders [77]. In sports medicine, for example, is generally used to assess adaptations related to resistance training [78] and exercise [17-19,29,38].

The difference in HRV between trained and untrained individuals has been widely investigated. Both variables in the time domain and frequency domain are higher in trained individuals compared to sedentary ones, indicating that HRV is higher in these individuals [16].

The regular practice of physical activity has been reported as a factor in increased vagal tone due to physiological adaptations that have occurred by the increase in cardiac work, since there is a decreased sensitivity of beta receptors [29]. Thus, the increase in parasympathetic modulation induces an electrical stability of the heart, while the high sympathetic activity increases the vulnerability of the heart and the risk of cardiovascular events [17].

Novais et al. [29] assessing the RMSSD, VLF, LF, HF, found no significant differences at rest between healthy sedentary men and active patients with AH and AMI, suggesting the effect of physical activity on autonomic modulation of these patients. This effect has also been proposed by Takahashi et al. [55], when analyzing the RMSSD index at rest in active coronary artery disease patients and healthy individuals, in which significant differences were also not found.

Moreover, these indexes also allow verification of the influence of factors such as age [4,7,37,79,80], gender [81-83] and exercise [17-19,29,38] on the autonomic control. Table 2 shows studies using HRV in various physiological and pathological conditions.

Table 1. Studies using comparatively the HRV in heart diseases.

Authors	Year	Disease	Assessed indexes	Conclusions
Reis et al. [64]	1998	AMI	Review Aticle	The positive predictive power of noninvasive methods is usually low, supporting the use of other resources in the stratification of post-AMI
Carnethon et al. [56]	2002	CAD	SDNN, HF	HRV can be used to identify differences in cardiac autonomic balance in healthy adults
Novais et al. [29]	2004	AH	RMSSD, VLF, LF, HF	No differences at rest between healthy and active individuals with AMI and AH
Menezes et al. [60]	2004	AH	SDNN, RMSSD, pNN50, HF, LF, LF/HF	HRV is decreased in hypertensive patients when compared to normotensive ones
Terathongkum et al. [61]	2004	AH	Review Article	Decreased HRV is an independent predictor of arterial hypertension in the patients
Takahashi et al. [55]	2005	CAD	RMSSD	There were no significant differences in HRV indexes in healthy sedentary and active coronary artery disease men
Bittencourt et al. [26]	2005	HC	RMSSD, pNN50, HF	There was a significant increase in parasympathetic modulation during controlled breathing associated with the tilt test in the patients
Pecyna [63]	2006	AMI	Indexes in time and frequency domain	HRV is decreased in post-AMI patients
Carney et al. [54]	2007	CAD	HF, LF, VLF	Moderate correlation was found between inflammatory factors and HRV in depressed coronary artery disease patients
Limongelli et al. [58]	2007	HC	SDNN, pNN50, RMSSD, LF, HF, LF/HF	The main clinical implication is the predictive value of HRV in risk stratification of children and young patients with HC
Karas et al. [59]	2008	AH	LF,HF,LF/HF	There was a reduction of hemodynamic responses (SAP and DAP) and sympathetic (LF) of elderly hypertensive
Larosa et al. [62]	2008	AMI	SDNN, frequency domain	HRV is decreased in patients with AMI

AMI: Acute myocardial infarction; CAD: Coronary artery disease; AH: Arterial hypertension; HC: Hypertrophic cardiomyopathy; HRV: Heart rate variability; SAP: Systolic arterial pressure; DAP: Diastolic arterial pressure

Table 2. Studies using comparatively the HRV in various conditions.

Authors	Year	Condition	Assessed indexes	Conclusions
Paschoal et al. [2]	2002	COPD	SDNN	With the evolution, the patients tend to have reduced HRV
Javorka et al. [38]	2002	Recovery after exercise	SDNN, RMSSD, pNN50, LF, HF	The cardiodeceleration after exercise is related to the immediate recovery, confirming parasympathetic contribution at this stage
Catai et al.[7]	2002	Aerobic training in young and middle age men	LF, HF, LF/HF	The vagal predominance during sleep is reduced with increasing age. The resting bradycardia induced by active postural maneuver suggests that adaptation is more related to intrinsic changes in sinus node than to vagal modulation
Weerapong et al. [41]	2005	Effects of the sportive massage	Review	Evidences of an increased parasympathetic activity and HRV. There is an increase of relaxing substances such as endorphins
Mello et al. [37]	2005	Age and physical activity	RMSSD, LF, HF, LF/HF	Aging reduces HRV. However, regular physical activity is likely to affect the vagal activity in the heart and consequently attenuates the effects of aging
Paschoal et al. [72]	2006	Different age-groups	RMSSD, pNN50, LF, HF, LF/HF	The HRV analysis is an important tool for investigating the cardiac autonomic function related to increasing age
Sin DD et al. [66]	2007	COPD	SDNN, SDANN, RMSSD, TINN	Nocturnal application of noninvasive mechanical ventilation for three months may improve HRV in patients with stable COPD
Kudaiberdieva et al. [65]	2007	Sudden death	Review article	The positive predictive value for sudden cardiac death remains low, requiring a combination of other markers
Lopes et al. [71]	2007	Age and resistance training	SDNN, pNN50, RMSSD	Aging causes changes in autonomic modulation on the sinus node, reducing HRV in middle-age individuals. The physical training studied did not change HRV
Neves et al. [73]	2007	Women post-menopause under estrogen therapy	SDNN, RMSSD, LF, HF, LF/HF	Estrogen therapy seems to attenuate the process of HRV reduction with increasing age, promoting a reduction in sympathetic activity on the heart
Furuland et al. [68]	2008	Renal failure	SDNN,LF	Chronic renal failure patients not undergoing dialysis presented reduced HRV

COPD: Chronic obstructive pulmonary disease; HRV: Heart rate variability

Lopes et al. [79] and Paschoal et al. [80] observed that the aging process causes a depletion of vagal tone and consequent increase in sympathetic activity, therefore older individuals have a lower HRV. In 2006, Rajendra Acharya et al. [4] observed that HRV is lower with age and the variation is greater in women. Melo et al. [37] in a study linking the effects of age and exercise showed that exercise training can mitigate these effects.

Ribeiro et al. [82] and Mercuro et al. [83] proposed that depression of hormone levels of estrogen that occurs during menopause, may be responsible for the reduction of HRV in elderly women. However, in a study by Neves et al. [81] greater vagal modulation and lower sympathetic in women were found when compared to men of similar age, suggesting that differences related to gender are not just hormone levels of estrogen.

Despite the widespread use of HRV analysis in understanding the phenomena involved with the SNA in normal and pathological conditions, studies related to its use in clinical practice are still scarce. However, some studies have shown the great potential that HRV analysis can have in clinical practice.

Godoy et al. [23], using indexes of HRV in the chaos domain, showed that these indexes can be used to predict morbidity and mortality in patients undergoing coronary artery bypass graft surgery. Patients with HRV indexes that showed a reduction in chaotic behavior showed increased rates of morbidity and mortality. The authors report that analysis of HRV indexes may be a new approach in clinical practice as prognostic tool in the preoperative evaluation of patients undergoing coronary artery bypass surgery.

Meyerfeldt et al. [84] assessed whether changes in HRV could serve as early warning signs of ventricular tachycardia and predict ventricular tachycardia of low or high frequency in patients with implantable cardioverter-defibrillators. The authors analyzed the time series of RR intervals stored on the device that had happened immediately before the onset of fibrillation, and compared it to a control period without tachyarrhythmia in 63 patients with chronic congestive heart failure. The comparison of these series showed that patients presented low HRV before the onset of episodes of ventricular tachycardia, which may allow the construction of devices with algorithms for early detection of arrhythmias.

Indexes of HRV have also been used as a tool for prediction of mortality among patients with acute myocardial infarction and depressed left ventricular systolic function [85,86] and in the characterization of a large number of morbid conditions, suggesting that the Heart Rate Variability can be a possible marker of homeostasis loss.

CONCLUSION

HRV has gained importance today as a technique to explore the ANS, which has an important role in maintaining homeostasis. Its use is diverse and it stands as mentioned above, as a predictor of the internal functions of the body, both in normal and pathological conditions. The widest possible use, the cost-effectiveness in the application of the technique and ease of data acquisition makes the HRV an interesting option for interpretation of the functioning of the ANS and a promising clinical tool to assess and identify impairments on health.

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