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Research Article

Evaluation of the Cardiac Autonomic Control of Patients with Arterial Hypertension

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Abstract

Background: Hypertension remains the most prevalent risk factor for cardiovascular diseases (CVD). Scientific literature had found a dysregulation of heart by autonomic nervous system in hypertensive patients. Objective: Our objective was to evaluate the autonomic nervous control of hypertensive Senegalese patients. Methods: This was a cross-sectional evaluating the autonomic nervous control of hypertensive patients by continuous recording of heart rate, in standing and lying position, using a Holter Shiller AR4Plus® ECG. Exporting the RR duration and it's incorporating it into the Kubios HRV Standard software made it possible to obtain the HRV parameters. HRV parameters were classified according reference values. Results: A total of 29 patients aged between 46 and 86 years were included in our study, and 21 of them were women. Controlled patients represented 27% of our population study and were, according to the use of beta-blockers, compared with patients not controlled. At rest, parasympathetic tone was found to be low in some patients. The sympathovagal balance was within normal limits except for some uncontrolled patients under beta-blockers. In orthostatic position, a significant decrease was noted in the parasympathetic tone while LF did not vary significantly. However, uncontrolled patients had a significantly higher LF in orthostatic position. But they did not show significant variation in their parameters while standing, unlike patients with good blood pressure control. Conclusion: Our results suggests that the functioning of the arterial baroreflex, which is the starting point of autonomic responses destined for the heart, is altered with rising blood pressure values.

Keywords

Arterial Hypertensive, Heart Rate Variability, Arterial Baroreflex

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1. Introduction

Hypertension remains the most prevalent risk factor for cardiovascular diseases (CVD) [1]. According to the WHO, hypertension and its associated complications, affecting over one billion people worldwide in 2023 [2]. Its prevalence is strongly influenced by the type of population studied, although it is generally estimated that this disease affects between 10 and 20% of the adult population and is responsible for 5.8% of all deaths worldwide. Arterial hypertension remains a significant public health concern, contributing to the onset of cardiovascular diseases, stroke, and premature death [2]. The mechanism behind the occurrence of this disease is linked to an alteration autonomic control of the arterial baroreflex which detects and regulates blood pressure (BP) by reflex effects on the heart and resistance vessels and renal excretion of sodium and water [3].

Cardiac autonomic neuropathy (CAN) thus contributes to the occurrence and maintenance of high blood pressure [3]. In CAN, decreased arterial baroreflex sensitivity (BRS) results in reduced baroreflex gain, and the resulting increased fluctuations in blood pressure variability may contribute to increased target organ damage and adverse outcomes [4]. In animal model BP variability and BRS closely correlated with organ damage, while decrease in BP variability and restoration of BRS contributed to organ protection besides the BP reduction [5]. In humans, impaired BRS is linked with morning BP rises [6] and morning hypertension is associated with higher cardiovascular risk [7]. Thus antihypertensive treatment should include not only drug's effectiveness in BP reduction, but also its possibility to affect BRS, BP variability and hear rate variability (HRV) [8]. Indeed, Milovanovic et al. have found un acute changes in heart rate, blood pressure, beat-to-beat heart rate variability and baroreflex sensitivity 30 minutes after 10 mg of enalapril [8].

Heart rate variability, based on the measurement of variation in the time interval between successive R-wave peaks of the QRS complex (R-R intervals), has emerged as a non-invasive and reliable tool for evaluating ANS activity [9]. Sympathetic function is assessed by BP variability to postural changes, while parasympathetic function is assessed by HR response to deep breathing, changes in posture (lying to standing) and the Valsalva maneuver [10]. The rising interest in HRV can partially be attributed to the feasibility of this method. R-R interval signals can be identified by means of several devices such as electrocardiographs and other sensors, and data are subsequently transmitted and processed by specialized programs developed to process and calculate HRV metrics [11]. HRV metrics are classified as either linear or nonlinear. Linear methods involve time-domain and frequency-domain indices [12, 13]. Studies carried out in non-African populations had found that LF and high-frequency spectral powers during supine were lowest in hypertensive, indicating diminished baroreflex modulation of RR intervals in hypertensive [14]. In Africa, more specifically in Senegal, we have not yet found any studies that have explored HRV in a hypertensive population. Thus, the objective of this present study was to evaluate the cardiac autonomic control of a population of Senegalese hypertensive.

2. Methods

2.1. Study Design

This was a cross-sectional study conducted in patients with arterial hypertension living in Senegal, West Africa Country. They had a single study visit which they provide all relevant personal. Clinical data were collected and the assessment of cardiac autonomic control was performed.

2.2. Patients

The study sample included 29 patients, the majority of whom were female (21 women and 8 men). Arterial hypertensive patients were enrolled from Cardiology Department of Dalal Jamm Hospital (Dakar, Senegal). Study was take between 01 November 2024 to 28 February 2025. All study participants provided written informed consent and information was anonymized before statistical analysis in accordance to Helsinki recommendations. Inclusion criteria were an established diagnosis of hypertension in adult patients aged at least 18 years, followed as outpatients at the Cardiology Department of Dalal Jamm Hospital. Exclusion criteria were the presence of a non-sinus heart rhythm on the EKG or lower limb amputation making standing difficult.

2.3. Data Measurement

2.3.1. Anthropometric Data

Anthropometric parameters such as the body weight of our patients, which was measured using a MyScale® brand bioimpedance analyzer after the subject's height and age were entered into the Fitdays software. The body mass index obtained was then classified according to reference standards [15].

2.3.2. Cardiovascular Data

Room experiment was quiet and its temperature constant. The measurements were taken one day a week (Wednesday, the day of the supervising cardiologist's outpatient consultation). All measurements took place in the morning.

(i) Blood pressure measurement

Blood pressure were measured in both arms and twice in supine position. Classification of resting blood pressure was done according to the European Society of Cardiology guidelines [16]. Tree leads holter electrocardiogram (EKG) were realized at rest 10 minutes at supine and 7 minutes on standing positions by an Holter EKG *AR4Plus Schiller*®.

(ii) Cardiac Autonomic Control

Cardiac autonomic nervous control was performed from the 5 min beat-to-beat time series constituted from inter-beat intervals from EKG R waves, i.e., the R-R interval. The HRV was assessed according to the consensual standards [12]. *Kubios HRV Standard* software were used to analyze HRV.

(iii) Time-Domain Analysis of HRV

HRV parameters such as the mean RR, heart rate (HR), the standard deviation of the RR (SDNN), the square root of the mean squared differences between adjacent normal RRI (RMSSD) and the percentage of successive normal beat lengths that differed more than 50 ms (pNN50) were collected.

(iv) Frequency-Domain Analysis of HRV

Spectral analyses by fast Fourier transform Welch's periodogram technique were used. These parameters included the power frequency (pw expressed in ms^2) in 3 frequency bands of interest: high frequencies (HF, 0.15-0.4 Hz) and low frequencies (LF, 0.04-0.15 Hz). The total power and LH/HF ratio were also computed. HF and LF powers were also expressed in normalized unit.

HRV parameters were classified according Sammito et al. [17] in low, normal and high.

2.4. Statistical Analysis

Statistics were performed using R statistical software version 4.3.1. Graphpad Prism software version 5.0 was used for the histogram design. Normality of variables distribution was checked by the Shapiro test. Data following the normal distribution were expressed as mean (SD). While those not following the normal distribution were expressed in Median (1st Quartile, 3rd Quartile). Comparison of parameters between supine and orthostatic positions or groups in accordance with blood pressure control was studied by unpaired t-test or the Kruslkal-wallis test according the result of Shapiro test. Research of interindividual variation of HRV parameters between lying to standing positions was carried out using the paired t-test. The significance threshold was set at $p < 0.05$.

3. Results

3.1. Patients Characteristics

A total of 29 known hypertensive patients were able to benefit from a valid measurement of heart rate variability. They were on average 63.52 ± 8.6 years old, ranging from 46 to 82 years. Our study population consisted mainly of men (n = 21). Mean body mass index was 25.9 ± 4.86 kg/m^2. Distribution of patients according to BMI classes is shown in the figure below.

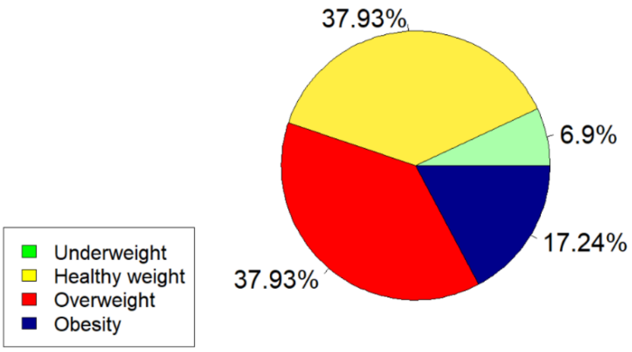

Figure 1. *Distribution of patients according to BMI classes.*

Analysis of this figure shows that more than half of the patients were overweight or obese. However, only one case of morbid obesity was found in our study population.

3.2. Arterial Blood Pressures

Mean systolic and diastolic blood pressures values were 147.3 ± 20.49 mmHg and 86.9 ± 11.75 mmHg, respectively. Classification of blood pressure values according the definition grade of hypertension by European Society of Cardiology/European Society of Hypertension is shown in Figure 2.

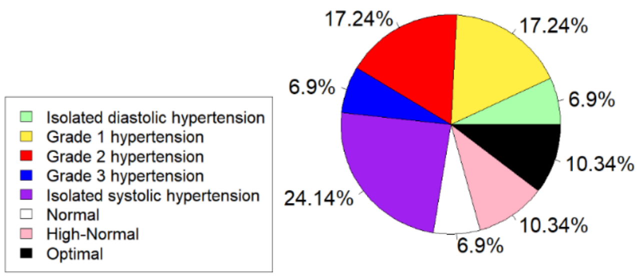

Figure 2. *Distribution of patients according to the definition of hypertension grade.*

Figure showed that approximately 27% of patients had values between the limits of normal, therefore normal blood pressure control.

None of the patients with normal blood pressure control were smokers or alcoholics. However, they were all sedentary. Studying of the repartition of patients according to the beta-blockers use between controlled and uncontrolled patients is shown in Figure 3.

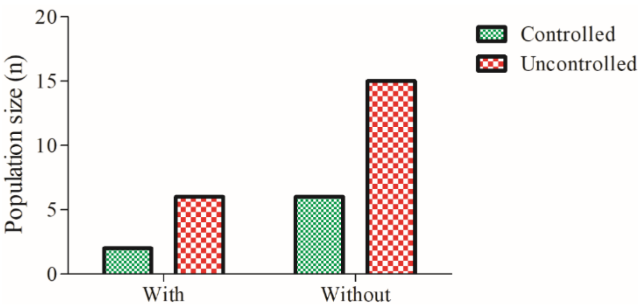

Figure 3. Distribution of patients according to beta-blocker use.

Analysis of this figure did not show a significant difference between taking beta-blockers and blood pressure control (p = 1).

3.3. Heart Rate Variability

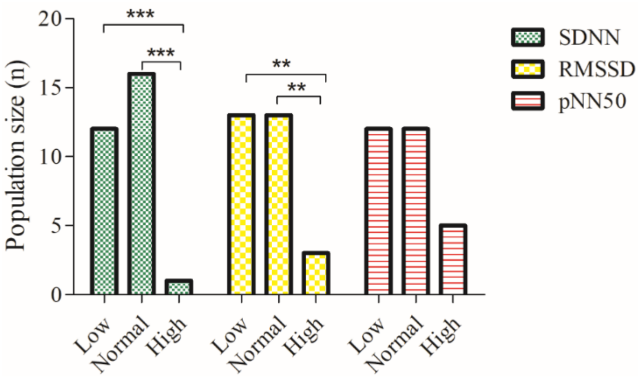

Figure 4. Distribution of patients according to the norms of temporal domain HRV parameters.

HRV parameters in the temporal and frequency domains were measured at rest in the supine position. Figure 4 shows the distribution of patients according to the classes obtained by using reference values for certain parameters of the time domain HRV.

Analysis of this figure shows that the temporal domain parameters exploring mainly the parasympathetic system such as SDNN and RMSSD were mostly low or normal. However, patients with high parasympathetic tone were significantly less important. Paradoxically, these patients did not have normal blood pressure control, but also three of them were on beta-blockers. HRV parameters of the frequency domain measured in supine position were also compared to reference values in Figure 5.

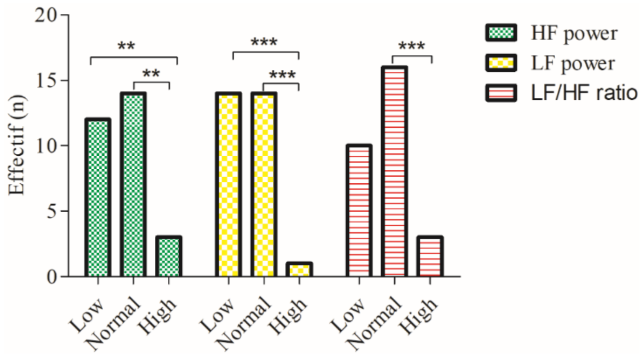

Figure 5. Distribution of patients according to reference values of HRV parameters of frequency domain.

Analysis of this figure shows that the frequency domain HRV parameters were found to be significantly low or normal. The same was true for the sympathovagal balance. However, patients with high sympathovagal balance had abnormal blood pressure control and two of them were on beta-blockers. We subsequently studied the variation of HRV parameters in the temporal and frequency domains between lying to standing (Table 1).

Table 1. Comparison of HRV parameters between lying to standing.

Analysis of this table shows a significant increase in heart rate when standing. Whereas the sympathetic tone explored by the LF did not increase significantly with increasing heart rate.

Parameters	**Lying** **N = 29[a]**	**Standing** **N = 29[a]**	**p**
RR (ms)	886 (128)	791 (132)	0.007
SDNN (ms)	22 (14, 34)	19 (14, 25)	0.4
HR (bpm)	69 (10)	78 (13)	0.006
RMSSD (ms)	17 (12, 26)	16 (11, 21)	0.2
pNN50 (%)	2 (0, 5)	1 (0, 2)	0.49
LF power (ms^2)	188 (87, 505)	146 (62, 184)	0.25
HF power (ms^2)	121 (42, 247)	57 (16, 155)	0.07

Parameters	Lying N = 29[a]	Standing N = 29[a]	p
LF power (n.u.)	58 (23)	63 (24)	0.43
HF power (n.u.)	42 (23)	37 (24)	0.42
Total power (ms^2)	383 (155, 849)	252 (124, 507)	0.19
LF/HF ratio	1.6 (0.7, 3.4)	1.7 (1.0, 5.0)	0.43

[a]Mean (SD); [a]Median (1st Quartile, 3rd Quartile)

When we performed a paired analysis to study the intra-individual variability of HRV parameters, other parameters varied significantly in addition to FC and RR. Indeed, RMSSD (p = 0.005; mean of differences = 6.02 ms), pNN50 (p = 0.01; mean of differences = 5.41%), HF (p = 0.03; mean of differences = 107.9 ms^2) and Total power (p = 0.02; mean of differences = 298.55 ms^2) decreased significantly in orthostatic position. On the other hand, sympathetic tone, by LF power, tended strongly towards decrease in orthostatic position (p = 0.06; mean of differences = 146.8 ms^2).

3.4. HRV and Blood Pressure Control

In supine position, the comparison of HRV parameters between patient groups according to blood pressure control showed only a significant decrease in pNN50 in controlled patients. However, in standing conditions, some differences were noted and represented in the following table.

Table 2. *Comparison of HRV parameters according to blood pressure control.*

Analysis of this table shows that patients with normal blood pressure control had lower parasympathetic heart rate variability parameters in the standing position. They also had significantly lower of VLF power, LF power and Total power.

Parameters	Controlled N = 8[a]	Uncontrolled N = 21[a]	p
RR (ms)	760 (163)	802 (121)	0.51
SDNN (ms)	14 (13, 16)	22 (16, 29)	0.02
HR (bpm)	82 (15)	76 (12)	0.38
RMSSD (ms)	12 (9, 18)	16 (12, 21)	0.2
pNN50 (%)	0 (0, 0)	1 (1, 3)	0.04
LF power (ms^2)	90 (53, 125)	167 (100, 311)	0.04
HF power (ms^2)	29 (16, 68)	85 (35, 185)	0.1
LF power (n.u.)	59 (14)	58 (26)	0.81
HF power (n.u.)	41 (14)	42 (26)	0.82
Total power (ms^2)	135 (97, 198)	388 (143, 543)	0.02
LF/HF ratio	1.6 (1.1, 3.2)	1.7 (0.8, 5.6)	0.75

[a]Mean (SD); [a]Median (1st Quartile, 3rd Quartile)

When analyzing the variation of HRV parameters within the group, we noted more significant changes in the controlled patients. Indeed, for the time domain HRV parameters, the variations were greater in the control group, with the exception of pNN50 (p = 0.04; mean of differences = 1.9% vs p = 0.02; mean of differences = 6.7%) and RMSSD (p = 0.001; mean of differences = 5.5 ms vs p = 0.03; mean of differences = 6.36 ms). Whereas HR (p = 0.008; mean difference = -10.9 bpm vs p < 0.0001; mean difference = -7.9 bpm) and RR interval (p = 0.001; mean difference = 114 ms vs p < 0.0001; mean difference = 88 ms). In the frequency domain HRV parameters, only patients with good blood pressure control showed a significant decrease of HF power in standing position ($p = 0.02$; mean of differences = 95.6 ms^2).

4. Discussion

Arterial hypertension is one of the most frequently found cardiovascular risk factors worldwide. This high blood pressure may be due to a change in cardiac control by the autonomic nervous system. This change may be due to an increase in resting sympathetic tone. Thus, the objective of our study was to explore this autonomous control in known hypertensive patients by measuring HRV at rest and in orthostatic position. Hypertensive patients, aged between 46 and 86 years with a male predominance, had been examined. Majority of them were on excess weight. Patients with good blood pressure control represented 27% of our population and were, according to the use of beta-blockers, compared with patients not controlled. Patients with good blood pressure control represented 27% of our population and were not significantly different from uncontrolled patients according to the use of beta-blockers. At rest, parasympathetic tone was found to be low in some patients. The sympathovagal balance was within normal limits except for some patients with abnormal blood pressure control under beta-blockers. In orthostatic position, a significant decrease was observed in the parameters of the parasympathetic system during the paired analysis. Patients with good blood pressure control responded better in orthostatic position with a more marked decrease in their parasympathetic tone.

4.1. Heart Rate Variability of Rest

In supine rest, HRV was low to normal in the vast majority of our patients. Indeed, parameters such as SDNN, RMSSD and pNN50, which explore control by the parasympathetic system, were found to be low in some patients. These results support those found in previous studies. Indeed, He et al.[18] in 2024 had conducted a study comparing HRV between hypertensive patients and normotensive subjects. The results had shown that hypertensive patients had lower parasympathetic tone with lower SDNN and RMSSD values. This decrease in parasympathetic tone had also been noted by Prakash et al. [14] in 2005 during a study comparing HRV in deep inspiration between normotensive subjects and hypertensive patients. They had found that hypertensive patients had lower HRV values than normotensive patients. This reduction in HRV serves as an indirect marker of autonomic nervous system dysfunction, signifying not only impaired autonomic regulation, but also an increased cardiovascular risk. [19, 20]. Patients with abnormal blood pressure control and who were on beta-blockers sometimes presented with high parasympathetic tone contrasting with a similarly high resting sympathovagal balance. This finding could be explained by the results of the study by Kiselev et al. [21] in 2014. Indeed, they had compared the effect of certain antihypertensive treatments on the autonomic control of the heart in these patients. Their results showed beneficial effects of beta-blockers on autonomic control with notable increases in HRV values as we noted in ours. The use of beta-blockers could contribute to the inhibition of the accelerating action of the sympathetic nervous system, thus lowering the heart rate. These effects could explain the increase in HRV parameters observed in some hypertensive patients compared to others. However, the sympathovagal balance which remains despite the effect of beta-blocker treatment could be related to the fact that Kiselev et al. [21] had noted more pronounced increases in LF than in HF.

4.2. Heart Rate Variability in Standing Position

In orthostatic position, apart from the HR and the RR interval, there were significant differences compared to the supine position. The other parameters only varied significantly in paired analysis, thus showing less variability between these two physiologically different states. Our results are consistent with those of Prakash et al. [14], who also found, apart from variations in HR and RR, an absence of significant variations in HRV parameters in orthostatic position. They had also shown that hypertensive patients did not significantly vary their LF power in orthostatic position, unlike their HF. Contrary to our results, Prakash et al. found a significant variation in standing position of LF and HF in normalize unit. These differences found between our studies could be explained by the number of patients, which was lower in Prakash's study where there were 25 hypertensive patients. The status of blood pressure control and the treatment taken were not explored in their study and could explain the differences observed between our two studies. We also noted that patients with normal blood pressure control had a more significant decrease in parasympathetic tone and a more significant increase in sympathetic tone. These results show that well-controlled patients respond better to orthostatic rest and therefore have an arterial baroreflex that is more within normal limits. Thus, the lack of blood pressure control exposes the patient to an alteration of the arterial baroreflex observed in this disease [14]. This alteration could promote the occurrence of cardiovascular complications [19, 20] hence the need for adequate management of hypertensive patients.

5. Conclusion

Measuring heart rate variability offers a non-invasive and inexpensive way to explore the heart's autonomic control. Indeed, continuous recording of RR intervals of the EKG allows us to obtain information on the behavior of the different components of the autonomic nervous system during simple maneuvers such as lying down and standing upright. In the case of hypertension, the pathophysiological mechanisms highlight an alteration of this control in favor of the sympathetic system. This is how our study showed that at rest in supine position, parasympathetic tone was either low or normal. However, in some patients on beta-blockers and with abnormal blood pressure control, high parasympathetic tone was sometimes noted, indicating the cardiomodator action of this molecule. However, this increase in parasympathetic tone was less than that of the sympathetic tone, thus giving a high sympathovagal balance. During the transition to orthostatic position, hypertensive patients exhibited less variation in their HRV parameters. And this was more pronounced in patients with poor blood pressure control. This suggests that the functioning of the arterial baroreflex, which is the starting point of autonomic responses destined for the heart, is altered with rising blood pressure values. This is why we recommend the evaluation of cardiac autonomic control in all hypertensive patients, but also appropriate management of their disease in order to reduce the risk of cardiovascular events.

Abbreviations

CVD	Cardiovascular Diseases
CAN	Cardiac Autonomic Neuropathy
BP	Blood Pressure
BRS	Baroreflex Sensitivity
ANS	Autonomic Nervous System
HRV	Heart Rate Variability
RR	RR Interval
SDNN	Standard Deviation of the NN Interval
HR	Heart Rate
RMSSD	Square Root of the Mean Squared Differences of Successive NN Intervals
pNN50	Percentage of Pairs of Adjacent NN Intervals That Differ by More than 50 Ms in the Entire Recording
LF	Low Frequencies
HF	High Frequencies
BMI	Body Mass Index

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Mor Diaw: Conceptualization, Formal Analysis, Writing – original draft, Wrating – review & editing

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Maimouna Toure: Data curation, Methodology, Validation

Fabienne Bregeon: Validation, Writing– original draft, Writing – review & editing

Stephane Delliaux: Validation, Writing– original draft, Writing – review & editing

Abdoulaye Ba: Validation, Writing– original draft, Writing – review & editing

Data Availability Statement

The data will be provided on request.

Conflicts of Interest

The authors declare no conflicts of interest.

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