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Original Article

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Relationship Between Cardiac Autonomic Control and Intradialytic Hypotension in Senegalese Chronic Hemodialysis Patients: A Single Center Prospective Study

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ABSTRACT

Background: Intradialytic hypotension (IDH) increases cardiovascular morbidity and mortality in chronic hemodialysis patients and cardiac autonomous neuropathy (CAN) might be involved. To assess cardiac autonomic control in hemodialysis patients and describe its relationship with IDH.
Methods: We conducted a prospective study at Ouakam Military Hospital in Senegal from January 1st to March 31st, 2023. Fifty-two patients (31 men, mean age 47.54 years) were included and had 3 measurements of heart rate variability (HRV): before, during and after an index hemodialysis session. They were classified according to changes in systolic blood pressure (SBP) during hemodialysis into three groups: 14 patients in group I (increase > 10 mmHg in mean intradialytic SBP), 13 in group II (decrease ≥ 20 mmHg in mean intradialytic SBP or MAP > 10 mmHg) and 25 in group III (others). HRV frequency domain indices between groups were compared.
Results: In pre-dialysis, patients in group II showed higher values in total power (650.30 vs. 94.94 and 108.11 ms^2, $p = 0.02$), high frequency (199.24 vs. 25.05 and 25.90 ms^2, $p = 0.03$) and low frequency (225.36 vs. 42.30 and 53.76 ms^2, $p = 0.01$) compared to those in groups I and III. Also, they presented less severe CAN (16.2% vs. 57.2% and 56%, $p = 0.03$). Measures after dialysis found no difference in HRV parameters among the three groups.
Conclusion: Our results found that HRV was similar between patients with and without IDH suggesting the influence of other risk factors that need to be explored in further studies.

Keywords: Autonomic nervous system; Heart rate; Hypotension; Renal dialysis; Senegal

INTRODUCTION

Intradialytic hypotension (IDH) is a common complication of hemodialysis and is associated with increased morbidity and mortality, especially from cardiovascular causes [1-3].
Its prevalence varies significantly across studies due to differing definitions. According to

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Conflicts of interest
All authors have no conflicts of interest to declare.

Data sharing statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' contributions
Conceptualization: ILS, AKS, BC, BM, SMS; Data curation: ILS, BM; Formal analysis: ILS, AKS, BM, SMS; Investigation: ILS, AKS, BC, BM, SMS; Methodology: ILS, AKS, SMS; Project administration: BC; Resources: BC, BM; Supervision: SMS; Validation: AKS, BC, BM, SMS; Writing - review & editing: BM, SMS.

the Kidney Disease Outcomes Quality Initiative and the European Best Practice Guidelines, IDH is a fall in systolic blood pressure (SBP) ≥ 20 mmHg or a fall in mean arterial pressure (MAP) of at least 10 mmHg associated with a clinical event and/or requiring nursing intervention [4,5]. This condition is particularly concerning because it often results in insufficient perfusion of vital organs, especially the heart and brain, which increases the risk of cardiovascular events and mortality.

The pathophysiology of IDH is multifactorial and not yet fully understood. However, hypovolemia induced by ultrafiltration (UF) during hemodialysis is considered as the primary etiological factor. In response to hypovolemia, the organism activates compensatory mechanisms to restore blood volume and maintain organ perfusion. These mechanisms include fluid exchange between interstitial and intracellular compartments to refill plasma volume, cardiovascular adaptations to sustain cardiac output and venous return, and arteriolar vasoconstriction to increase total peripheral resistance [6]. All of these processes are primarily regulated by the sympathetic nervous system. Thus, any dysfunction in the autonomous nervous system (ANS), such as cardiac autonomous neuropathy (CAN) may impair these compensatory mechanisms, thereby increasing the risk of IDH [7-9].

Cardiac autonomic function can be noninvasively assessed through the measurement of heart rate variability (HRV) that provides time and frequency domain parameters. Frequency domain parameters improve the diagnosis of CAN by 3 times compared to time domain parameters [10]. However, current data supporting the clinical validation of HRV to predict IDH in hemodialysis patients are still inconsistent [11]. Previous studies have shown that during hemodialysis, the sympathetic response is normally activated, particularly in patients without CAN while in patients experiencing IDH, this sympathetic response is often impaired, particularly in the later phases of dialysis, contributing to the occurrence of hypotension [12]. Conversely, Sapoznikov et al. [13] observed that the arterial baroreflex mechanism is preserved and adequately activated during hemodialysis in patients with IDH, suggesting that the pathophysiology of IDH may be complex and not solely attributable to sympathetic dysfunction.

While several studies explored the relationship between cardiac autonomic function and IDH, there is a lack of data on this topic among African dialysis patients who have different demographic characteristics and comorbidities. This study was designed to assess cardiac autonomic control in chronic hemodialysis patients at Ouakam Military Hospital in Senegal and to explore its potential relationship with IDH.

METHODS

Type, setting and study period

This was a cross-sectional, single center study from January 1 to March 31, 2023. Participants were recruited from the hemodialysis unit of Ouakam Military Hospital (Dakar).
HRV recordings were read and interpreted by a physiologist at the Physiology and Functional Explorations Laboratory at Cheikh Anta Diop University in Dakar.

Study population

All patients over 18 years of age who had been on regular chronic hemodialysis for at least 3 months, who consented to participate in the study and who had not been hospitalized for an acute disease during the month prior to data collection, were included. Patients with cardiac arrhythmias or pacemakers, and those with a short life expectancy due to a chronic disease such as terminal cancer, were not included.

Ethics approval and consent to participate

The participation to this study was voluntary. All participants provided informed consent. The principles of anonymity and confidentiality of data were respected during this study. The study was approved by the Institutional Review Board at the Ouakam Military Hospital (Reference: 02/2022/CER/HMO; Clinical trial number: not applicable).

Study procedure

For each included patient, we first conducted a thorough and targeted interview to assess, among other factors, sociodemographic information, medical history, and current treatments particularly antihypertensive medications (calcium channel blockers and blockers of the renin angiotensin aldosterone system). A general examination was then carried out, including measurements of blood pressure (BP), weight and HRV recording during an index hemodialysis session. All included patients were treated with the same type of machine (BBRAUN) for 4 hours. The dialysis bath had the same composition in all patients (Ca^{2+}: 1.5 mmol/L; Na^{+}: 138 mmol/L; K^{+}: 2 mmol/L; Mg^{2+}: 0.5 mmol/L; HCO_3^-: 32 mmol/L and glucose: 1 g/L) during the index hemodialysis session. Their treatment had not been modified or stopped during the study period. Hemodialysis parameters for the index session and biological data were collected from dialysis and medical records respectively. Finally, the data were entered into a Microsoft Excel version 16.77.1 file (Microsoft, Redmond, WA, USA) and analyzed using R software (R Foundation for Statistical Computing, Vienna, Austria).

BP monitoring and patients' classification

BP was meticulously measured using a single, reliable and validated electronic BP monitor before and after the hemodialysis sessions (OMRON®, Osaka, Japan). Intradialytic BP data were taken from the BBRAUN hemodialysis monitor.

Pre-dialysis measurement

BP was measured 30 minutes prior to the start of the hemodialysis session under controlled conditions: in a quiet, well-lit room at ambient temperature to minimize external factors affecting BP and from an arm without an arterio-venous fistula. The patient was positioned in the supine position and in the orthostatic position to assess orthostatic BP changes.

Intradialytic measurement

During the hemodialysis session, BP was regularly measured every 30 minutes using the BBRAUN hemodialysis monitor. The BP measurements were taken at rest, ensuring the patient remained as calm and relaxed as possible. It was also measured at the lowest level of symptoms experienced by the patient.

Post-dialysis measurement

After the hemodialysis session, BP was measured after a 30-minute rest in the supine position, in a manner similar to the pre-session measurements.

Patients' classification

Following the international guidelines on IDH [5], all included patients were classified into three groups according to their intradialytic BP variations. Group I consisted of patients whose mean SBP raised by more than 10 mmHg during the session, compared with the resting pre-dialysis SBP. Group II comprised patients with a decrease in mean SBP ≥ 20 mmHg or a fall in MAP of at least 10 mmHg associated with a clinical event and/or requiring nursing intervention during hemodialysis session [4,5]. This corresponded to patients prone to IDH. Group III included all patients who could not be classified into either of these two groups.

HRV monitoring and analysis

HRV was recorded using an *AR4plus Schiller*® ECG Holter (SCHILLER, Baar, Switzerland), a lightweight, patient-comfortable device with 5 electrodes. The electrodes were placed on the patient's bare torso in the supine position 30 minutes before the session and removed 30 minutes later. The HRV was recorded throughout this period. We took measures during early, middle and late phases of the dialysis session [14].

Pre-dialysis HRV monitoring

The first HRV recorded was measured for 10 minutes in the supine position to assess baseline autonomic function. Following this, a second set of recording was taken for 7 minutes in the standing position to observe the effects of postural changes on autonomic regulation.

Post-dialysis HRV monitoring

It was measured during 10 minutes in the supine position, 20 minutes after the session.

Intradialytic HRV monitoring

During the hemodialysis session, HRV data were collected in 5-minute intervals, resulting in a total of 48 segments throughout the 4-hour session. This allowed for continuous monitoring of autonomic function during different phases of dialysis. For statistical analysis, the hemodialysis session was divided into three phases based on the timing of monitoring: early phase: corresponding to segments 1 and 2 (the first 10 minutes of the session), middle phase: corresponding to segments 24 and 25 (approximately the halfway point of the session) and the late phase: corresponding to segments 47 and 48 (the last 10 minutes of the session). Each phase consisted of 2 consecutive 5-minute segments, and the mean value of the two segments was used as the final variable for analysis. This approach helped to mitigate the natural variability of HRV and provided a more stable and accurate estimate of autonomic function during each phase of hemodialysis.

HRV data analysis

The HRV recordings were analyzed using Kubios HRV Standard software (Kubios Oy, Kuopio, Finland), which is a widely recognized tool for HRV analysis. The software provided various frequency domain parameters, each reflecting different aspects of autonomic control over the heart. High frequency (HF) explored parasympathetic activity while low frequency (LF) reflected sympathetic activity in particular. Very low frequency (VLF) reflected long-term heart rate regulatory mechanisms such as thermoregulation and hormonal mechanisms. The total power (TP) represented the total variance and corresponds to the sum of the LF, HF and VLF spectral bands. The LH/HF ratio represents an indicator of sympatho-vagal balance, with high values reflecting the dominance of the sympathetic system and low values reflecting the dominance of the parasympathetic system.

CAN diagnosis

CAN was retained using the criteria proposed by Bellavere et al. [15] with a TP measured in supine position at rest lower than the average—two standard deviation (2SD) of its diabetic population without CAN.

CAN was rated moderate if HFpw and LFpw were below the mean—2SD of their values in the moderate CAN population.

It was severe if HFpw and LFpw are lower than the mean—2SD of the values in their diabetic population with a severe form of CAN.

Patients who had low TP with LFpw and HFpw values greater than the mean—2SD of the HFpw and LFpw values found in the moderate form of CAN were classified as borderline.

Statistical analysis

Data analysis was performed using R software version 4.3.2. Continuous data were tested for normality using the Shapiro test. Data following a normal distribution were expressed as the means ± standard deviations or medians (interquartile ranges) for those not following a normal distribution. Categorical data were expressed as frequencies (proportions, %). A χ^2 test or Fisher's exact test will be used to compare categorical data. Comparisons of variables following a normal distribution between groups was carried out by analysis of variance, and in the event of significance, Tukey's post-hoc test was used. For non-normally distributed data, medians were compared using the nonparametric Kruskal-Wallis test and if the results were significant, the Wilcoxon post-hoc test was used. Individual variability between different HRV measurement conditions was studied using a paired Student's t-tests. The significance threshold was set at $p < 0.05$.

RESULTS

Patient characteristics

Fifty-two patients were included and classified into group I (n = 14; 26.9%), group II (n = 13; 25%) and group III (n = 25; 48.1%) (**Fig. 1**). The mean age of the patients was 47.54 ± 15.08 years with a male predominance (59.6%). Patients in the group II were significantly older than those in the group III. The most common cause of end-stage renal disease was undetermined nephropathy. Arterial hypertension was the most prevalent

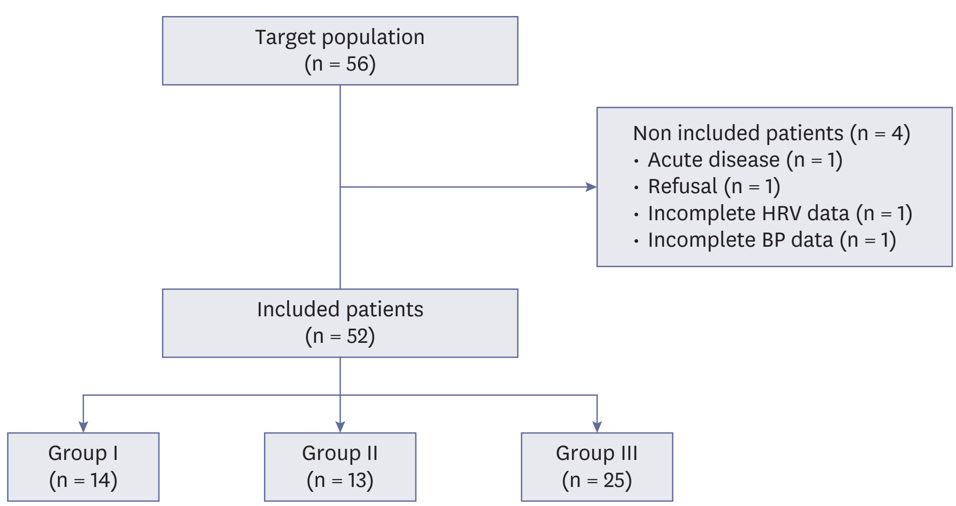

Fig. 1. Flow chart of patients. Group I: patients with BP increase in dialysis. Group II: patients with intradialytic hypotension. Group III: patients neither in Group I nor in Group II.
BP, blood pressure; HRV, heart rate variability.

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comorbidity affecting 94.23% of patients, followed by left ventricular hypertrophy that was present in 40.40% of patients (**Table 1**).

There were no significant differences between the groups regarding SBP or diastolic blood pressure before the hemodialysis session. However, as expected, SBP at the end of the session was significantly higher in patients in the group I compared to those in the other groups (**Table 1**).

Table 1. Comparison of sociodemographic characteristics; comorbidities; and clinical, biological and dialysis parameters between the 3 groups

Data	Total (n = 52)	Group I (n = 14)	Group II (n = 13)	Group III (n = 25)	p-value
Sociodemographic parameters and comorbidities					
Age (yr)	47.54 ± 15.08	52.5 ± 11.2	54.08 ± 16	41.36 ± 14.4*	0.01
Male gender	31 (59.6)	5 (35.7)	7 (53.8)	19 (76)††	0.04
Duration on dialysis (mo)	46.60 ± 0.26	48.60 ± 0.3	47.90 ± 0.2	44.6 ± 0.2	0.52
Initial kidney disease undetermined	24 (46.2)	6 (42.9)	6 (46.2)	12 (48)	0.81
Nephropathy attributed to hypertension	14 (26.9)	5 (35.7)	4 (30.8)	5 (20)	
Diabetic nephropathy	3 (5.8)	0 (0)	0 (0)	3 (12)	
Others	11 (21.2)	3 (21.4)	3 (23.1)	5 (20)	
Arterial hypertension	49 (94.23)	13 (92.86)	12 (92.31)	24 (96)	0.86
Diabetes	4 (7.69)	0 (0)	0 (0)	4 (16)	0.09
Smoking	1 (1.9)	0 (0)	1 (7.7)	0 (0)	0.21
Alcohol	1 (1.9)	0 (0)	0 (0)	1 (4)	0.57
LVEF < 55%	4 (7.7)	1 (7.1)	1 (7.6)	2 (8)	0.78
LVH	21 (40.4)	5 (35.7)	7 (53.8)	9 (36)	0.10
Clinical parameters					
BMI (kg/m²)	22.3 ± 5.6	22.72 ± 7.6	24.73 ± 6.2	20.74 ± 3.4	0.11
SBP (before HD)	161.1 ± 23.1	156.9 ± 18.7	168.3 ± 23.7	159.7 ± 24.9	0.4
DBP (before HD)	99.17 ± 16.1	93.29 ± 12.2	99.77 ± 16.6	102.2 ± 17.3	0.25
HR (before HD)	80.65 ± 13.9	77.14 ± 12.9	78.15 ± 13.8	83.92 ± 14.3	0.26
SBP (ortho)	162.5 ± 23.3	168.8 ± 14	166.1 ± 22.6	157.4 ± 27.2	0.29
DBP (ortho)	102.5 ± 16.1	100.86 ± 11.2	100.92 ± 22.2	104.1 ± 15.5	0.78
HR (ortho)	88.02 ± 15.6	84.69 ± 13.97	87.58 ± 17.3	89.96 ± 15.8	0.62
HR (Valsalva)	78.58 ± 13.6	78.57 ± 13.3	74.62 ± 14	80.64 ± 13.7	0.44
SBP (after HD)	166.0 ± 29.7	189.4 ± 23.1	147.5 ± 25††	162.5 ± 25††	0.0001
DBP (after HD)	99.02 ± 17.7	104.2 ± 14.05	90.31 ± 18.62	100.6 ± 16.23	0.07
HR (after HD)	79.17 ± 13.97	79.86 ± 14.13	79 ± 13.26	78.8 ± 14.94	0.97
RAASB	36 (69.23)	9 (64.29)	9 (69.23)	18 (72)	0.88
BB	9 (17.31)	4 (28.57)	2 (15.38)	3 (12)	0.38
Biological parameters					
Hemoglobin (g/dL)	8.81 ± 1.58	8.50 ± 1.43	9.5 ± 1.41	8.72 ± 1.69	0.32
Hematocrit (%)	26.13 ± 3.99	24.66 ± 2.43	29.2 ± 2.09	25.33 ± 4.68	0.13
Calcemia (mg/L)	83.82 ± 12.55	81.45 ± 15.26	87.29 ± 14.76	83.93 ± 9.84	0.69
Phosphatemia (mg/L)	34.96 ± 19.14	34.32 ± 22.4	40.24 ± 21.09	32.92 ± 17.47	0.72
iPTH (pg/mL)	520 (1,092)	265 (1,038)	546 (1,286)	587 (808)	0.67
Albuminemia (g/L)	39.5 ± 6.56	40.5 ± 13.43	41 ± 2.82	37 ± 2.82	0.87
Dialysis session parameters					
AVF	40 (76.92)	13 (92.86)	11 (84.62)	16 (64)	0.09
Blood flow	300.4 ± 30.2	292.9 ± 27.85	303.1 ± 35.68	303.2 ± 29.39	0.56
Hourly UF	593.4 ± 182	491.5 ± 236.4	587.7 ± 127.5	653.5 ± 53.4†	0.02
Mean SBP	160.1 ± 27.2	176.9 ± 18.4	146.2 ± 22.4††	157.9 ± 23.8†	0.002
Mean DBP	82.54 ± 17.1	75.07 ± 13.52	85 ± 18.87	85.44 ± 16.67	0.15
Mean HR	76.88 ± 12.2	73.3 ± 13.87	78.54 ± 14.6	77.96 ± 10.12	0.47
KT/V	1.29 ± 0.25	1.36 ± 0.26	1.41 ± 0.24	1.21 ± 0.23*	0.04
URR (%)	71.66 ± 7.76	73.00 ± 7.77	72.66 ± 8.04	72.66 ± 7.7	0.54

Data are expressed as mean ± standard deviation, number (%).
AVF, arteriovenous fistula; BB, betablockers; BMI, body mass index; DBP, diastolic blood pressure (mmHg); HD, hemodialysis; HR, heart rate (bpm); iPTH, intact parathormone; LVEF, left ventricular systolic ejection fraction; LVH, left ventricular hypertrophy; RAASB, renin angiotensin aldosterone system blocker; SBP, systolic blood pressure (mmHg); UF, ultrafiltration; URR, urea reduction rate.
The p-value between groups II and III, *$p < 0.05$.
The p-value between group II and other groups, †$p < 0.05$, ††$p < 0.01$.

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Table 2. Comparison of HRV parameters between the three groups

Data	Total (n = 52)	Group I (n = 14)	Group II (n = 13)	Group III (n = 25)	p-value
Supine position					
TP (ms^2)	128.13 (301.15)	94.94 (219.48)	650.30 (832.20)*	108.11 (255.1)	0.02
HF (ms^2)	40.73 (138.51)	25.05 (68.8)	199.24 (516.22)*	25.90 (109.62)	0.03
LF (ms^2)	58.13 (173.56)	42.30 (122.42)	225.36 (457.72)	53.76 (99.86)†	0.01
VLF (ms^2)	16.36 (29.01)	10.99 (20.64)	28.17 (30.25)	14.48 (23.33)	0.07
LF/HF	1.72 (2.17)	1.83 (1.67)	1.74 (2.17)	1.72 (2.46)	0.76
Orthostatism					
TP (ms^2)	110.30 (220.1)	106.00 (134.6)	257.85 (504.8)	58.33 (182.39)	0.05
HF (ms^2)	19.22 (53.88)	22.79 (36.87)	60.50 (205.9)	15.31 (28.03)	0.19
LF (ms^2)	41.94 (127.49)	39.23 (65.97)	152.30 (233.1)*	33.01 (117.6)†	0.04
VLF (ms^2)	15.74 (31.56)	17.26 (28.11)	25.52 (33.07)	13.35 (16.85)	0.13
LF/HF	1.78 (3.12)	1.72 (2.78)	1.59 (2.98)	2.14 (4.86)	0.99
After hemodialysis session					
TP (ms^2)	243.97 (682.2)	193.31 (469.4)	623.40 (624.4)	177.09 (542.2)	0.23
HF (ms^2)	85.96 (276.44)	35.58 (206.34)	253.16 (145.29)	76.57 (119.92)	0.39
LF (ms^2)	127.16 (432.4)	129.23 (236.2)	133.09 (471.84)	112.30 (435.2)	0.25
VLF (ms^2)	22.48 (39.67)	20.81 (26.28)	23.28 (96.35)	19.72 (45.31)	0.24
LF/HF	1.79 (2.38)	1.75 (1.65)	2.57 (3.84)	1.70 (1.97)	0.62

Table 2 shows that markers of autonomous nervous system activity in the three groups are significantly different before hemodialysis session with those in group II presenting higher variability and better response when they shift to orthostatic position. Patients in the group III with low values of TP, LF and HF presented a poor response to orthostatism probably due to severe dysautonomia. However, those differences between groups disappeared after the hemodialysis session.
HF, high frequency; HRV, heart rate variability; LF, low frequency; TP, total power; VLF, very low frequency.
*p-value between group II and the other groups, $p < 0.05$.
†p-value between groups II and III, $p < 0.05$.

Regarding the session parameters, the mean hourly UF rate of patients in the group III was significantly higher than those in group I. The KT/V of the patients in the group II was significantly higher than that of patients in the group III (**Table 1**).

HRV before the hemodialysis session

In the decubitus position, patients in the group II showed higher values in TP (650.30 vs. 94.94 and 108.11 ms^2, p = 0.02), HF (199.24 vs. 25.05 and 25.90 ms^2, p = 0.03) and LF (225.36 vs. 42.30 and 53.76 ms^2, p = 0.01) compared to than those in groups I and III. Also, they exhibited a lower prevalence of severe CAN (16.2% vs. 57.2% and 56%, p = 0.03) (**Table 2**). Additionally, the severity of CAN in these patients was less pronounced than in the other groups (**Table 3**).

In orthostatic position, the LF values of patients in the group II were significantly higher compared to those in the other groups (**Table 2**). Upon transitioning to orthostatism, patients in groups II and III exhibited a significant reduction in TP, with no notable changes observed in other HRV parameters or SBP. In contrast, group I showed no significant variation in HRV parameters during the transition to orthostatism. Additionally, arterial baroreflex was significantly impaired in the majority of patients (**Fig. 2**).

Table 3. Patients' level of cardiac autonomic control

Data	Group I (n = 14)	Group II (n = 13)	Group III (n = 25)	p-value
Normal	0 (0.0)	3 (23.1)	1 (4.0)	0.05
Borderline	3 (21.4)	4 (30.1)	3 (12.0)	0.36
Moderate CAN	3 (21.4)	4 (30.1)	7 (28.0)	0.84
Severe CAN	8 (57.2)	2 (16.7)*	14 (56.0)†	0.03
p-value	0.005	0.77	0.0001	

CAN, cardiac autonomous neuropathy.
*p-value between group II and the other groups, $p < 0.05$.
†p-value between groups II and III, $p < 0.05$.

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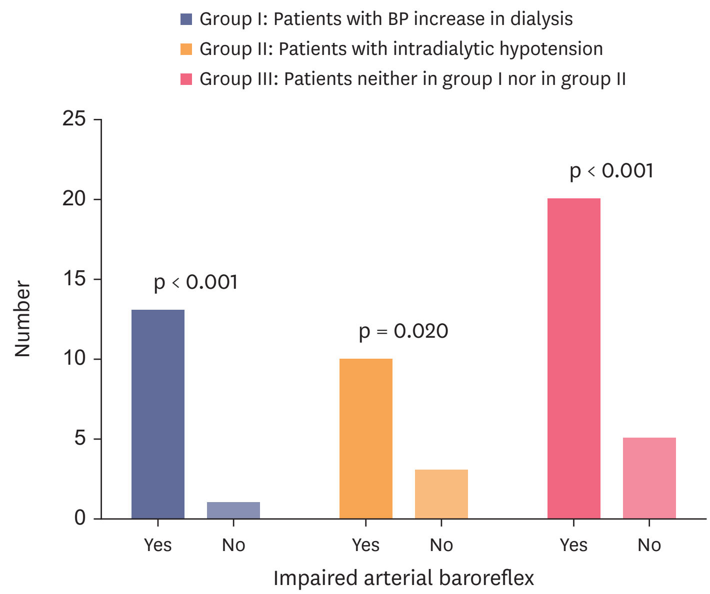

Fig. 2. Arterial baroreflex status according to patient group.
BP, blood pressure.

Patients with IDH exhibited the best HRV prior to the hemodialysis session. However, the sympathetic response during the transition to orthostatism was impaired in the majority of patients.

HRV during the hemodialysis session

The TP, HF and LF of the middle phase of patients in the group II were significantly higher than those in the group III. There was no significant difference in these parameters during this phase between patients in the group II and those in group I. During the early and late phases of the hemodialysis session, the HRV parameters were comparable among the three groups (**Fig. 3**). Patients with IDH seemed to have the best HRV during the middle phase of the hemodialysis session.

HRV after the hemodialysis session

At the end of the hemodialysis session, there were no significant differences in HRV parameters between the three groups (**Table 2**). However, patients in the group I showed a slight impairment in TP, while those in the group III exhibited more severe alteration of autonomic function (low values of TP and LF). In contrast, there was no significant change in HRV values pre- and post-dialysis for patients in the group II. This shows a better adaptation capacity in these patients.

DISCUSSION

ANS dysfunction is a major cause of IDH because it impairs the body's ability to regulate BP during hemodialysis.

Several previous studies assessing the clinical significance of HRV in dialysis patients has been demonstrated in association with IDH [16], vascular accesses failure [17], major adverse

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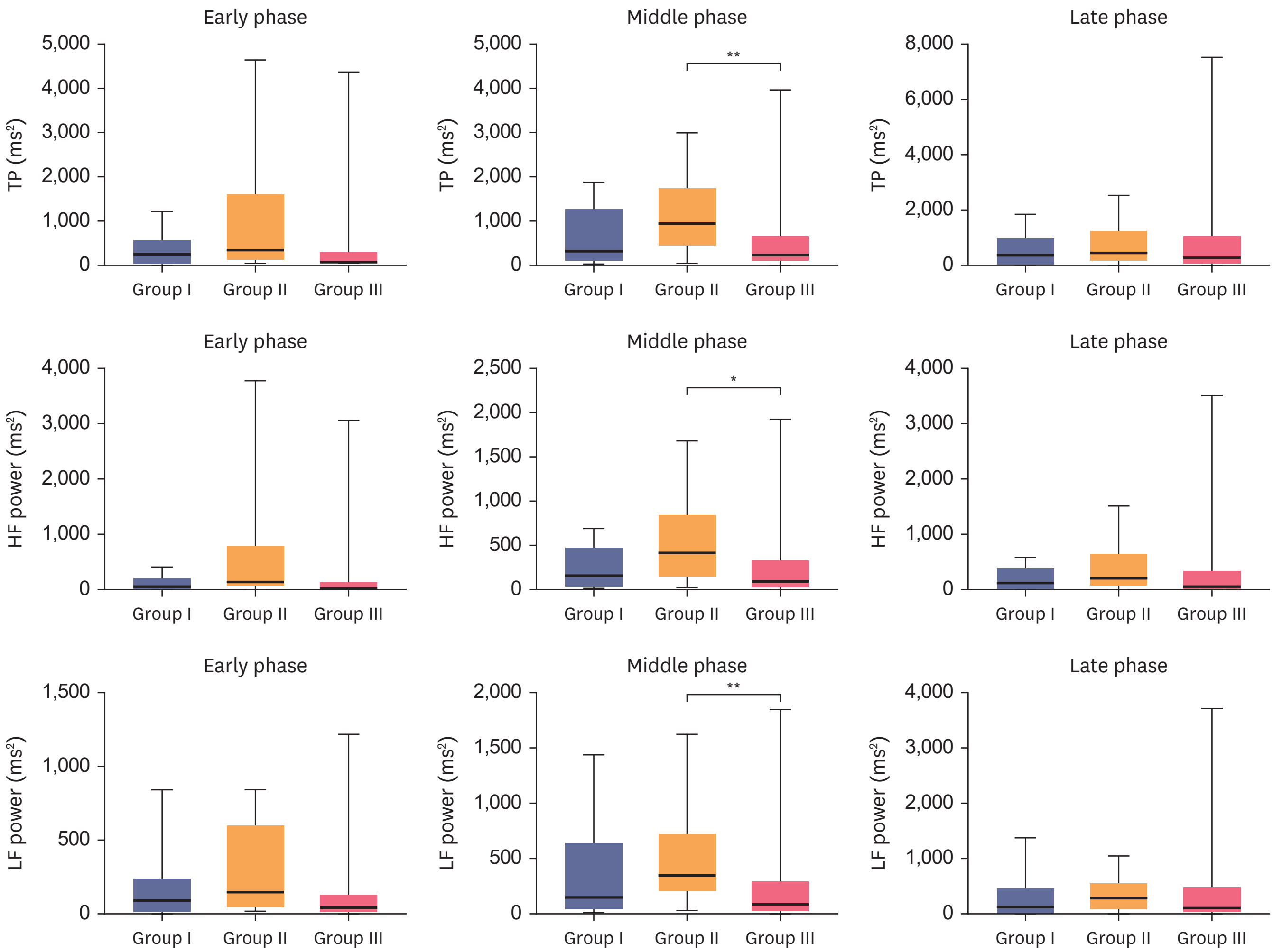

Fig. 3. Comparison of frequency-domain parameters during the dialysis session.
Group I: patients with blood pressure increase in dialysis. Group II: patients with intradialytic hypotension. Group III: patients neither in group I nor in group II.
HF, high frequency; LF, low frequency; TP, total power.
The p-value between groups II and III, $^{*}p < 0.05$, $^{**}p < 0.01$.

cardiovascular events [18], and mortality [7] in hemodialysis patients. To our knowledge, the present study is the first one in African patients.

Patients with IDH presented the best HRV values before the hemodialysis session. This was evidenced by TP and LF parameters, which were significantly higher in patients belonging to group II (with IDH) than those in the other groups. In addition, severe CAN was significantly more common in patients in groups I and III (**Table 3**). This finding is in contradiction with majority of data in the literature that reported a significantly higher incidence of IDH among patients with CAN [2,6,9,12]. However, similarly to our results, Straver et al. [7] found no significant difference in resting cardiac autonomic control between patients with and without IDH. Furthermore, a study by Chang et al. [19] did not find any significant difference in resting HRV parameters in patients with an increase in SBP > 20 mmHg and those with a decrease in SBP > 20 mmHg.

The absence of significant link between ANS dysfunction and incidence of IDH in our study could be explained by several factors. In their study, Straver et al. [7] measured HRV with

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spectral analysis and demonstrated its superiority in detecting vegetative dysautonomia compared to traditional tests. Skin sympathetic nerve activity is another methods that can help assessing noninvasively the sympathetic nerve activity and detect early dysfunction [2]. Other parameters that may influence the HRV tests in our patients include their young age and short dialysis vintage that make them less prone to autonomic nervous dysfunction, preserved autonomic, impaired vascular resistance or plasma refill. In the study by Chang et al. [19], patients were older (61.70 ± 12.60 vs. 54.08 ± 16) and with more comorbidities such as diabetic nephropathy (44.40% vs. 0%), ischemic heart disease (22.20% vs. 0%) or heart failure (15.60% vs. 7.60%). These conditions are known to have a negative influence on HRV values [20-22]. Moreover, dialysis parameters dialysate composition, ultrafiltration rate might interfere with CAN control mechanism and induce hypotension during dialysis [11].

The sympathetic response during the transition to orthostatism was impaired in all our patients. There are few data in the literature evaluating changes in HRV indices during the transition to orthostatism by the spectral method in chronic hemodialysis patients. González et al. [23] reported a stimulated sympathetic activity, from supine position to orthostatism, in chronic hemodialysis patients. This stimulation is marked by a decrease in RR and increases in standard deviation of NN intervals, LFnu and Ln LF/HF. In our study, the absence of significant variability in HRV parameters between the supine and orthostatic positions found corroborates the impaired arterial baroreflex noted in the majority of them and reflects a poor cardiac autonomic control.

Patients with IDH had better HRV during the middle phase of hemodialysis as demonstrated by the TP, LF and HF of this phase, which were significantly higher in patients in group II compared to group III. The other HRV parameters did not significantly differ between the groups during this phase. These results are similar to those reported by Sapoznikov et al. [13] who noted that episodes of IDH were associated with significant increases in LF and HF mainly in patients with severe IDH without LF/HF variation. The magnitude of the increase in these indices was proportional to the decrease in BP. Thus, the results of Sapoznikov et al. [13] showed a preserved and adequately activated baroreflex during IDH. Chang et al. [19] noted an increase in the LF/HF ratio in patients undergoing dialysis, with a decrease in both LF and HF (with a more marked decrease in HF than LF) at rest and during the dialysis session. However, as mentioned above, those patients with IDH were older and presented with more comorbidities such as diabetes and cardiovascular disease which could influence HRV values at rest and during the hemodialysis session [20-22]. CAN leads to poorer HRV due to impaired autonomic control, particularly in diabetes and other chronic conditions. However, our findings suggest that patients who experience IDH, actually had preserved HRV implying that other factors besides CAN might be more prominent the occurrence of IDH.

Moreover, HRV seems to improve during the hemodialysis session in some of our patients. When comparing pre- and post-session values, a significant improvement in HRV was noted in groups I and III. In contrast, patients in the group II exhibited no significant variation in HRV parameters between the two periods.

Indeed, previous studies reported a significant correlation between HRV and Kt/V indices, suggesting a beneficial effect of dialysis adequacy on ANS [24]. Further studies are needed to confirm whether this represents a sustained improvement.

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Limitations of the study

Our study has several limitations that should be considered when interpreting the results.

First, the cross-sectional nature can limit causal conclusions and the small sample size may affect the statistical power. Additionally, not all patients underwent a comprehensive cardiovascular assessment to identify potential cardiac abnormalities contributing to IDH, nor did we perform a full hormonal work-up, such as plasma catecholamine assays.

Second, we excluded patients with arrhythmias but not those taking these antihypertensive medications (beta-blockers, angiotensin-converting enzyme inhibitors, and angiotensin II) due to the limited number of participants. However, the distribution of these medications was similar across the three groups (**Table 1**). Third, HRV was measured during only one dialysis session and may not reflect intra-individual variability. The cut-off values used for HRV were derived from studies in diabetic populations and may not be validated in hemodialysis patients. Finally, the absence of synchronized continuous BP and HRV monitoring limits a precise assessment of baroreflex function and real-time fluctuations in BP during hemodialysis.

Conclusion

Our results suggest that chronic hemodialysis patients who are prone to IDH had better HRV at rest and during the middle phase of the hemodialysis session. This contradictory finding suggest the existence of other risk factors such as young age, intravascular volume changes, vascular resistance, and cardiovascular reflexes that interfere with the occurrence of IDH. The improved HRV observed in some patients at rest and during the middle phase might reflect a preserved ANS or a compensatory response to hemodynamic changes. Further studies are necessary to better explore the determinants of IDH in African patients.

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