The correlation between ambulatory blood pressure parameters and cardiovascular risk factors in older adults with high-risk hypertension

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Abstract

Objective: To explore the correlation of 24-hour ambulatory blood pressure (BP) monitoring (ABPM) parameters and cardiovascular risk factors in older adults with high-risk hypertension. **Material and method:** A cross-sectional study was conducted on 96 older adults (≥ 60 years old) with treated high-risk hypertension. Socio-demographic and cardiovascular risk information were gathered. The patients were performed 24-hour ABPM. **Results:** The mean age was 70.88 ± 7.86 years, and 64.6% were women. The prevalence of cardiovascular risk factors was as follows: dyslipidemia: 80.2%, family history of hypertension: 54.2%, diabetes mellitus: 51%, smoking: 24%, prior stroke: 11.5%. Significant differences in 24-hour, awake, and sleep systolic BP were observed between men and women. There were significant correlations between 24-hour mean systolic BP with age (r = 0.229, p = 0.025), dyslipidemia (r = 0.223, p = 0.029), family history of hypertension (r = 0.214, p = 0.036), BMI (r = 0.212, p = 0.039), waist circumference (r = 0.226, p = 0.027) and creatinine level (r = 0.207, p = 0.043). There were significant correlations between 24-hour mean diastolic BP with BMI (r = 0.289, p = 0.004) and prior stroke (r = -0.224, p = 0.029). There were significant correlations between 24-hour mean BP with BMI (r = 0.268, p = 0.009), waist circumference (r = 0.220, p = 0.032) and prior stroke (r = -0.215, p = 0.036). **Conclusion:** There were significant correlations between ABPM parameters and cardiovascular risk factors in older adults with high-risk hypertension.

Keywords: *24-hour ambulatory blood pressure*, *cardiovascular risk factors, high-risk hypertension, older adults, correlation.*

1. INTRODUCTION

Hypertension is widely recognized as a major risk factor for cardiovascular morbidity and mortality [1]. Ambulatory blood pressure measurement (ABPM) has emerged as the recommended method for diagnosing and managing hypertension, with increasing utilization in older adults [2]. Previous studies have demonstrated that 24-hour ABPM exhibits stronger correlations with cardiovascular risk factors and provides more accurate predictions of cardiovascular morbidity and mortality compared to office blood pressure (BP) measurements [3,4]. Despite the growing adoption of ABPM in Vietnam, there remains a scarcity of research focusing on this issue in the older population. Therefore, the aim of this study was to investigate the correlation between 24-hour ABPM parameters and cardiovascular risk factors in older patients with high-risk hypertension.

2. MATERIALS AND METHODS

2.1. Study design and participants

The study was conducted as a cross-sectional investigation at the Department of Internal Medicine of Becamex International Hospital in Binh Duong province, Vietnam, from June 2020 to June 2021. The inclusion criteria included patients aged 60 and above, diagnosed with high-risk hypertension, and undergoing inpatient antihypertensive treatment. Participants were required to consent to participate in the study and be on continuous antihypertensive medication during ABPM measurements. Exclusion criteria included secondary hypertension, hypertensive patients under 60 years old with low to moderate risk, untreated hypertension, acute illnesses or severe electrolyte disturbances, less than 85% of the ABPM measurement time completed, and non-consenting individuals.

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DOI: 10.34071/jmp.2023.6.4

Recieved: 14/7/2023; Accepted: 12/12/2023; Published: 31/12/2023

Hypertension diagnosis and management adhered to the 2018 recommended treatment guidelines of the Vietnam Heart Association and the Vietnamese Hypertension Society [5]. High-risk hypertensive patients were defined as individuals with grade 1 hypertension accompanied by three or more risk factors or target organ damage, stage 3 chronic kidney disease, diabetes mellitus (DM), cardiovascular disease, or grade 2 hypertension accompanied by one or more risk factors [5].

2.2. Data collection

The variables of interest included patient clinical characteristics, cardiovascular risk factors, co-morbidities, physical examination data, blood tests, and electrocardiography and echocardiography data. Left ventricular hypertrophy (LVH) was defined as an left ventricular mass index (LVMI) exceeding 95 g/m² in women and 115 g/m² in men [6].

Patients underwent 24-hour ambulatory blood pressure monitoring (ABPM) after measuring their clinical BP. The Oscar2 device by SunTech Medical Inc was used for measurements. ABPM data were analyzed with AccuWinpro v3.4 software. BP readings were taken at specific intervals according to European Society of Hypertension guidelines [7]. Participants were recorded sleep and wake times and avoided strenuous activities. Valid records included at least 85% reliable measurements, excluding abnormal readings. BP readings below 70 mmHg or above 260 mmHg (systolic) and below 40 mmHg or above 150 mmHg (diastolic) were excluded from analysis.

In our study, we evaluated nocturnal BP changes and circadian rhythms using a formula: (daytime BP - nighttime BP)/daytime BP [7]. We classified patients as "Dippers" if nighttime systolic and diastolic BP reduction exceeded 10% of daytime BP, "Extreme Dippers" if it exceeded 20%, "Non-Dippers" if systolic and/or diastolic BP were less than 10%, and "Risers" if nighttime systolic and/or diastolic BP exceeded daytime BP [7].

The study adhered to the principles outlined in the Declaration of Helsinki and was independently approved by the local Ethics Committee of the Hue University of Medicine and Pharmacy (Approval No. H2020/346, June 18, 2020).

2.3. Statistical analysis. Statistical analysis was performed using IBM SPSS Statistics 25.0 (SPSS Inc., Chicago, IL, USA). The assessment of normality in the distribution of continuous variables was tested by the Kolmogorov-Smirnov test. Continuous variables with a normal distribution were expressed as mean (M) and standard deviation (SD), while non-normally distributed variables were presented as median (Me) and interquartile range (IQR). Categorical variables were expressed as numbers and percentages. Comparisons of categorical variables were performed using the Chi-Square and Fisher's exact tests, while continuous variables were analyzed using the unpaired Student t-test and Mann–Whitney U test. Pearson's correlation test and Spearman's correlation test were employed for correlation analysis. Significance was considered when $p < 0.05$ for all analyses.

3. Results

3.1. General characteristics of the population

The study included a total of 96 patients, with a mean age of 70,88 ± 7,86 years, 64.5% women (n = 62). Based on their BMI, 28 participants (29.2%) were classified as obese and 26 patients (27.1%) were overweight. A total of 24 participants (25%) were diagnosed with hypertension in stage 1, 23 (24%) in stage 2 and 17 (17.7%) stage 3. The mean clinical systolic BP (SBP) and diastolic BP (DBP) of all participants were 150.16 ± 26.06 and 81.46 ± 11.79 mm Hg, respectively. The prevalence of cardiovascular risk factors was as follows: dyslipidemia: 80.2% (n = 77), family history of hypertension: 54.2% (n = 52), diabetes mellitus: 51% (n = 49), smoking: 24% (n = 23), prior stroke: 11.5% (n = 11). Results of laboratory and instrumental methods were shown in Table 1.

Table 1. Laboratory and instrumental findings of study participants

Variable	Total (n = 96)	Men (n = 34)	Women (n = 62)	P
Creatinine, µmol/l, Me (IQR)	84.6 (90.4; 99)	96.1 (83.9; 113)	75.7 (67; 91.1)	< 0.001
Estimated GFR, ml/min/1.73 m^2, Me (IQR)	70.3 (56.7; 83.1)	71.7 (57.2; 85.1)	70 (56.4; 82.4)	0.756
Total Cholesterol, mmol/l, Me (IQR)	4.30 (3.62; 4.97)	4.1 (3.3; 4.8)	4.3 (3.8; 5.0)	0.161
HDL-c, mmol/l, Me (IQR)	0.85 (1.05; 1.26)	1.0 (0.8; 1.2)	1.1 (0.9; 1.3)	0.092
LDL-c, mmol/l, Me (IQR)	2.49 (1.76; 3.11)	2.5 (1.5; 2.9)	2.6 (1.8; 3.4)	0.419
Triglyceride, mmol/l, Me (IQR)	1.61 (1.22; 2.20)	1.6 (1.1; 2.1)	1.6 (1.3; 2.3)	0.553
Glucose, mmol/l, Me (IQR)	6.25 (5.30; 8.17)	6.8 (5.8; 8.6)	6.0 (5.2; 8.0)	0.107

Uric acid, mmol/l, Me (IQR)	334.95 (279.32; 435.72)	373.7 (305.3; 467.2)	319.3 (266.2; 428.5)	< 0.001
LVH, n (%)	49 (51)	17 (50)	32 (51.6)	1.0
LVM, g, M±SD	157.55 ± 52.72	179.58 ± 52.09	145.47 ± 49.41	< 0.001
LVMI, g/m^2, M±SD	107.73 ± 37.26	123.49 ± 37.94	99.08 ± 34.19	0.002
LVEF, %, M±SD	65.51 ± 6.94	64.21 ± 8.75	66.23 ± 5.67	0.231

Abbreviation: *GFR - Glomerular filtration rate, HDL-c - High density lipoprotein cholesterol, IQR - interquartile range, LDL-c - Low density lipoprotein cholesterol, LVEF - Left ventricular ejection fraction, LVH - Left ventricular hypertrophy, LVM - Left ventricular mass, LVMI - Left ventricular mass index, Me - Median.*

Parameters of 24-hour ambulatory blood pressure monitoring as shown in Table 2. The mean 24-hour SBP was 130.80 ± 17.43 mmHg, DBP was 73.73 ± 10.17 mmHg, and the mean 24-hour BP was 92.79 ± 11.84 mmHg. Men had significantly higher mean values for 24-hour, awake, and sleep SBP, while there were no gender differences in mean 24-hour, awake, sleep DBP and 24-hour BP. The nocturnal BP fall was categorized as dippers (systolic and diastolic) in 13.5% of patients, non-dippers (systolic and/or diastolic) in 53.1%, and risers (systolic and/or diastolic) in 56.3%. Extreme Dippers were not observed.

Table 2. Characteristics of clinical blood pressure and 24-Hour Ambulatory Blood Pressure Monitoring Parameters in Study Participants

Variable	Total (n = 96)	Men (n = 32)	Women (n = 62)	P
Clinical SBP, mmHg, M±SD	150.16 ± 26.06	154.41 ± 25.07	147.82 ± 26.50	0.231
Clinical DBP, mmHg, M±SD	81.46 ± 11.79	82.65 ± 9.15	80.81 ± 13.03	0.422
24-hour mean SBP, mmHg, M±SD	130.80 ± 17.43	135.44 ± 13.55	128.26 ± 18.85	0.034
24-hour mean DBP, mmHg, M±SD	73.73 ± 10.17	75.09 ± 9.00	72.98 ± 10.75	0.328
24-hour mean BP mmHg, M±SD	92.79 ± 11.84	95.21 ± 9.60	91.47 ± 12.79	0.14
Awake mean SBP, mmHg, M±SD	131.10 ± 17.52	135.44 ± 13.69	128.73 ± 18.99	0.049
Awake mean DBP, mmHg, M±SD	73.76 ± 10.39	74.88 ± 9.09	73.15 ± 11.06	0.436
Sleep mean SBP, mmHg, M±SD	128.76 ± 19.77	135.06 ± 15.43	125.31 ± 21.12	0.02
Sleep mean DBP, mmHg, M±SD	73.24 ± 10.93	75.00 ± 8.98	72.27 ± 11.81	0.244
Dipping status:				
- Dippers (systolic and diastolic), n (%)	13 (13.5)	2 (5.9)	11 (17.7)	0.129
- Extreme Dippers (systolic and diastolic), n (%)	0	0	0	-
- Non-Dippers (systolic and/or diastolic), n (%)	51 (53.1)	22 (64.7)	29 (46.8)	0.134
- Riser (systolic and/or diastolic), n (%)	54 (56.3)	23 (67.6)	31 (50)	0.132

Abbreviation: DBP - Diastolic blood pressure, M - Mean, SBP - systolic blood pressure, SD - Standard deviation.

3.2. 24-hour mean systolic blood pressure and cardiovascular risk factors

The univariate linear regression analysis as shown in Table 3, 24-hour mean SBP was positively correlated with age (r = 0.229, p = 0.025), dyslipidemia (r = 0.223, p = 0.029), family history of hypertension (r = 0.214, p = 0.036), BMI (r = 0.212, p = 0.039), waist circumference (r = 0.226, p = 0.027) and creatinine level (r = 0.207, p = 0.043).

Table 3. The correlation of 24-hour mean systolic blood pressure load with cardiovascular risk factors

Variables	24-hour systolic mean (mmHg)				
	β	α	r	r^2	P
Age, years	0.508	94.780	0.229	0.052	0.025
Diabetes mellitus	-2.363	134.323	-0.068	0.005	0.509
Smoking	-3.462	136.897	-0.085	0.007	0.409
Dyslipidemia	9.696	119.187	0.223	0.05	0.029
Prior stroke	-9.464	148.646	-0.174	0.03	0.09
Family history of hypertension	7.456	119.928	0.214	0.046	0.036
BMI, kg/m^2	1.121	104.538	0.212	0.045	0.039
Waist circumference, cm	0.321	100.791	0.226	0.051	0.027
Creatinine, µmol/l	0.139	118.553	0.207	0.043	0.043
Estimated GFR, ml/min/1.73 m^2	-0.178	143.223	0.191	0.036	0.063
Glucose, mmol/l	0.581	126.386	0.147	0.022	0.154
Total cholesterol, mmol/l	0.847	127.025	0.059	0.004	0.565
Triglyceride, mmol/l	-0.545	131.867	0.036	0.001	0.729
HDL-c, mmol/l	3.748	126.807	0.065	0.004	0.526
LDL-c, mmol/l	1.056	128.018	0.074	0.005	0.476
LVM, g	-0.014	132.979	0.042	0.002	0.686
LVMI, g/m^2	-0.023	133.236	0.048	0.002	0.640
LVH	-2.639	132.149	-0.076	0.006	0.461
LVEF, %	0.109	123.645	0.043	0.002	0.674

Abbreviation: *BMI - Body mass index, GFR - Glomerular filtration rate, HDL-c - High density lipoprotein cholesterol, LDL-c - Low density lipoprotein cholesterol, LVEF- Left ventricular ejection fraction, LVH - Left ventricular hypertrophy, LVM - Left ventricular mass, LVMI - Left ventricular mass index.*

3.3. 24-hour mean diastolic blood pressure and cardiovascular risk factors

The univariate linear regression analysis showed that 24-hour mean DBP positively correlated with BMI (r = 0.289, p = 0.004) and negatively correlated with prior stroke (r=-0.224, p=0.029) (Table 4).

Table 4. The correlation of 24-hour mean diastolic blood pressure load with cardiovascular risk factors

Variables	24-hour diastolic mean (mmHg)				
	β	α	r	r^2	p
Age, years	-0.137	83.464	0.106	0.011	0.313
Diabetes mellitus	3.276	76.583	-0.095	0.009	0.356
Smoking	0.074	73.578	0.003	0	0.976
Dyslipidemia	3.973	68.949	0.156	0.024	0.128
Prior stroke	-7.106	87.106	-0.224	0.05	0.029
Family history of hypertension	1.252	71.883	0.062	0.004	0.551
BMI, kg/m^2	0.897	52.718	0.289	0.084	0.004
Waist circumference, cm	0.161	58.697	0.194	0.037	0.058
Creatinine, µmol/l	-0.003	74.005	0.008	0	0.945
Estimated GFR, ml/min/1.73 m^2	0.001	73.686	0.001	0	0.991
Glucose, mmol/l	0.354	71.038	0.153	0.024	0.133

Total cholesterol, mmol/l	1.068	68.963	0.129	0.017	0.208
Triglyceride, mmol/l	0.617	72.525	0.07	0.005	0.509
HDL-c, mmol/l	2.304	71.273	0.069	0.005	0.505
LDL-c, mmol/l	1.013	71.056	0.121	0.015	0.232
LVM, g	-0.001	730.900	0.006	0	0.952
LVMI, g/m^2	0.001	730.578	0.005	0	0.966
LVH	-0.905	74.170	-0.045	0.002	0.665
LVEF, %	0.065	69.479	0.044	0.002	0.67

Abbreviation: *BMI - Body mass index, GFR - Glomerular filtration rate, HDL-c - High density lipoprotein cholesterol, LDL-c - Low density lipoprotein cholesterol, LVEF- Left ventricular ejection fraction, LVH - Left ventricular hypertrophy, LVM - Left ventricular mass, LVMI - Left ventricular mass index.*

3.4. 24-hour mean blood pressure and cardiovascular risk factors

The univariate linear regression analysis showed that 24-hour mean BP positively correlated with BMI (r = 0.286, p = 0.009), waist circumference (r = 0.220, P = 0.032) and negatively correlated with prior stroke (r=-0.215, p=0.036) (Table 5).

Table 5. The correlation of 24-hour mean blood pressure load with cardiovascular risk factors

Variables	24-hour mean blood pressure (mmHg)				
	β	α	r	r^2	p
Age, years	0.072	87.66	0.048	0.002	0.642
Diabetes mellitus	-2.093	95.909	-0.089	0.008	0.39
Smoking	-1.132	94.784	-0.041	0.002	0.692
Dyslipidemia	5.772	85.878	0.195	0.038	0.057
Prior stroke	-7.936	107.754	-0.215	0.046	0.036
Family history of hypertension	3.238	88.070	0.137	0.019	0.183
BMI, kg/m^2	0.965	70.165	0.268	0.072	0.009
Waist circumference, cm	0.212	72.936	0.220	0.048	0.032
Creatinine, µmol/l	0.041	89.142	0.091	0.008	0.38
Estimated GFR, ml/min/1.73 m^2	-0.056	96.691	0.088	0.008	0.394
Glucose, mmol/l	0.42	89.602	0.156	0.024	0.129
Total cholesterol, mmol/l	1.005	88.309	0.104	0.011	0.314
Triglyceride, mmol/l	0.189	92.423	0.018	0	0.86
HDL-c, mmol/l	2.916	89.683	0.075	0.006	0.468
LDL-c, mmol/l	1.029	90.078	0.106	0.011	0.306
LVM, g	-0.006	93.72	0.026	0.001	0.8
LVMI, g/m^2	-0.007	93.574	0.023	0.001	0.825
LVH	-0.534	93.574	-0.065	0.004	0.529
LVEF, %	0.082	87.466	0.048	0.002	0.644

Abbreviation: *BMI - Body mass index, GFR - Glomerular filtration rate, HDL-c - High density lipoprotein cholesterol, LDL-c - Low density lipoprotein cholesterol, LVEF- Left ventricular ejection fraction, LVH - Left ventricular hypertrophy, LVM - Left ventricular mass, LVMI - Left ventricular mass index.*

4. DISCUSSION

In our study, the mean 24-hour SBP was 130.80 ± 17.43 mmHg, the mean 24-hour DBP was 73.73 ± 10.17 mmHg, and the mean 24-hour BP was 92.79 ± 11.84 mmHg. Men demonstrated significantly higher mean values for 24-hour, awake, and sleep SBP. However, there were no gender differences in the mean 24-hour, awake, and sleep DBP, as well as the 24-hour BP. These findings align with a study by Wendelin-Saarenhovi et al. [8] involving 502 hypertensive patients aged ≥ 64 years, which reported similar trends in BP measurements. The study showed that the ambulatory blood pressure daytime value of 130/83 mmHg corresponded best to the office BP value of 140/90 mmHg. Both office and ambulatory BP values were significantly higher in women than in men. Furthermore, the normal values of ambulatory blood pressure were markedly lower than the office BP values. Even when treated, hypertensive individuals tended to have elevated BP values compared to normotensive individuals [8]. These results highlighting the gender differences in SBP and the overall higher BP values in men compared to women. The 24-hour ambulatory BP monitoring provides a more comprehensive and accurate assessment of BP levels compared to traditional office BP measurements. This is particularly important in identifying and managing hypertension in both men and women, considering the gender-specific differences observed.

The present study demonstrated significant correlations ABPM parameters, such as 24-hour mean systolic and diastolic BP, and traditional cardiovascular risk factors. These findings align with previous research and add to the existing body of evidence. Consistent with previous studies, we observed a positive correlation between 24-hour mean systolic BP and age [9]. Studies such as the Framingham Heart Study and the National Health and Nutrition Examination Survey (NHANES) have shown that SBP tends to increase while DBP decreases after the age of 60, regardless of hypertension status [9]. Moreover, isolated systolic hypertension is a prevalent form of hypertension in older adults, accounting for a significant proportion of cases [10, 11]. Our findings further support the prognostic value of 24-hour mean SBP in predicting cardiovascular mortality, as demonstrated by Burr et al., where each 10-mmHg rise in SBP yielded a relative hazard ratio of 1.17 (95% confidence intervals 1.09 - 1.26; $P < 0.001$) [12]. The significant correlations observed between 24-hour mean SBP and various factors, including age, BMI, waist circumference, creatinine level, dyslipidemia, and family history of hypertension, align with previous studies [13 - 15]. Chuwa et al. conducted a study in Tanzania, involving university employees, and reported similar correlations, except for family history of hypertension [13]. Furthermore, the prevalence of dyslipidemia in our study population was consistent with previous findings, supporting the correlation between dyslipidemia and elevated BP [13]. These results indicate the relevance of considering these factors in assessing an individual's BP and cardiovascular risks.

Regarding 24-hour mean diastolic BP, we found significant correlations with BMI and prior stroke, consistent with previous research [13,16]. The inverse relationship between diastolic BP and cardiovascular risk, particularly coronary heart disease, was well-established [17, 18]. Lower diastolic BP have been associated with an increased risk of cardiovascular events [17, 18]. Our study reinforces the importance of monitoring diastolic BP as part of cardiovascular risk assessment.

In our study, we found that the mean 24-hour SBP exhibited a stronger correlation with cardiovascular risk factors compared to the mean 24-hour DBP and mean 24-hour BP. This observation is consistent with previous studies conducted in hypertensive subjects and large population-based studies. For instance, a study involving 136 hypertensive subjects, aged between 29 and 83 years, demonstrated similar findings, as did large population-based studies involving 11.135 adults with a median age of 54.7 years [15, 19]. Yang et al. conducted a study that specifically examined the predictive value of various ABPM profiles. Their findings revealed that the mean 24-hour SBP had the highest hazard ratio for predicting cardiovascular events compared to other ABPM profiles [19]. This further supports the notion that mean ambulatory BP is a crucial indicator of an individual's cardiovascular risk and emphasizes the need for lifestyle modifications targeting modifiable risk factors such as dyslipidemia and obesity.

5. CONCLUSION

To conclude, our study contributes to the increasing evidence supporting the significant correlations between ABPM parameters and cardiovascular risk factors. The results further emphasize the importance of ABPM in assessing an individual's cardiovascular risk and guiding appropriate management strategies. Future research should explore these correlations in larger and more diverse populations to further validate our findings.

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