Correlation between 24-hour urinary sodium excretion and blood pressure control status in patients with resistant hypertension: A single-center cross-sectional postprint study

Authors: Wang Qinghai, Li Shicheng, Wu Yanxiang, Wang Chenyu, Yan Xiaowei

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Abstract

Objective To analyze the relationship between 24-hour urinary sodium excretion and the control status of office blood pressure and home blood pressure monitoring (HBPM) in patients with resistant hypertension (RH). Methods Using the RH database from the cardiology outpatient clinic of Peking Union Medical College Hospital, RH patients who visited between October 2017 and March 2018 were enrolled in this cross-sectional study. Patients' 24-hour urinary sodium was measured, and their office blood pressure, HBPM levels, and clinical medication use were recorded concurrently. Based on the quartiles of 24-hour urinary sodium levels of all patients, the subjects were divided into four groups: low, low-medium, medium-high, and high urinary sodium. Multivariate logistic regression was used to analyze risk factors affecting blood pressure control status in RH. Results A total of 202 RH patients were enrolled, including 107 males and 95 females, with a mean age of (59.87 ± 16.30) years. The mean 24-hour urinary sodium level was (198.92 ± 96.59) mmol. Younger patients and those with higher body mass index had higher urinary sodium levels (both $P < 0.001$). With increasing urinary sodium, the number of antihypertensive medication classes increased significantly ($P = 0.001$), and the control rates of morning and forenoon HBPM were lower ($P = 0.040$, 0.032). Multivariate logistic regression analysis showed that 24-hour urinary sodium level was independently associated with control status of office blood pressure (OR 2.356, 95% CI 1.004-5.533, $P = 0.049$), HBPM morning blood pressure (OR 2.408, 95% CI 1.026-5.650, $P = 0.030$), and HBPM forenoon blood pressure (OR 2.299, 95% CI 1.031-5.129, $P = 0.033$), but showed no significant association with control status of afternoon and nighttime HBPM blood pressure (both $P > 0.05$). Conclusion 24-hour urinary sodium is an independent correlate of office blood pressure and morning

and forenoon HBPM target achievement in RH patients, and sodium restriction plays an important role in reducing blood pressure variability and promoting blood pressure target achievement in RH patients.

Full Text

Correlation Between 24-Hour Urinary Sodium Excretion and Blood Pressure Control Status in Patients with Resistant Hypertension: A Single-Center Cross-Sectional Study

WANG Qinghai[1], LI Shicheng[2], WU Yanxiang[1], WANG Chenyu[1], YAN Xiaowei[1]

[1] Department of Cardiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing 100730, China
[2] Department of Cardiology, People' s Hospital of Guangxi Zhuang Autonomous Region, Nanning 530021, China
Corresponding author: YAN Xiaowei, Tel: 86-10-69155068, E-mail: xswy_pumc@163.com

Abstract

Objective: To investigate the correlation between 24-hour urinary sodium excretion and the control status of office blood pressure (BP) and home blood pressure monitoring (HBPM) in patients with resistant hypertension (RH).

Methods: A cross-sectional study was conducted based on the RH patient database at Peking Union Medical College Hospital. All RH patients treated in the Department of Cardiology from October 2017 to March 2018 were enrolled. Twenty-four-hour urinary sodium excretion (24h-UNa) was measured to estimate daily sodium intake. Office BP, HBPM (four measurements daily: before morning medication, 10 a.m., 4 p.m., and before sleep at night), and antihypertensive drug regimens were recorded. Based on the quartiles of 24h-UNa excretion, all enrolled patients were stratified into four groups: low 24h-UNa, low-mid 24h-UNa, mid-high 24h-UNa, and high 24h-UNa groups. Multiple logistic regression analysis was used to identify independent factors associated with BP control rates.

Results: A total of 202 subjects were recruited (107 men, 95 women) with a mean age of (59.87±16.30) years. The mean 24h-UNa was (198.92±96.59) mmol. Patients with higher urinary sodium excretion were younger and had higher body mass index (BMI) ($P<0.001$). The number of antihypertensive drugs increased significantly with rising urinary sodium levels ($P=0.001$). High urinary sodium excretion was associated with reduced BP control rates for HBPM in the morning and at 10 a.m. Multivariate logistic regression analysis showed that 24h-UNa was independently associated with the achievement of office BP control

(OR=2.356, 95% CI 1.004-5.533, P=0.049), morning HBPM (OR=2.299, 95% CI 1.031-5.129, P=0.033), and 10 a.m. HBPM (OR=2.408, 95% CI 1.026-5.650, P=0.030), but not with 4 p.m. or nighttime HBPM control status.

Conclusions: 24h-UNa is an independent risk factor for the control rates of office BP and morning HBPM in RH patients. Restriction of sodium intake plays an important role in reducing BP fluctuation and improving BP control.

Keywords: resistant hypertension; 24-hour urinary sodium excretion; office blood pressure; home blood pressure monitoring

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Introduction

Hypertension is a chronic cardiovascular disease resulting from the interaction of genetic and environmental factors. High sodium intake is a crucial environmental factor affecting blood pressure. Global estimates attribute 1.65 million cardiovascular deaths annually to sodium intake exceeding 2.0 g/day. Studies demonstrate that for every 2.3 g increase in daily salt intake, systolic BP rises by 5-7 mmHg and diastolic BP by 1.7 mmHg, while sodium reduction has clear antihypertensive effects.

Resistant hypertension (RH), a special type of hypertension, represents a major challenge in clinical management, with a prevalence of 5-30%. Chinese expert consensus recommends routine assessment of sodium intake in RH patients, as excessive salt consumption may play an important role in poor BP control. However, reports on the relationship between salt intake and BP control status in RH patients remain limited.

Home blood pressure monitoring (HBPM) provides extensive BP measurements outside medical settings, offering important out-of-office BP assessment for screening masked hypertension, predicting cardiovascular risk, and evaluating treatment efficacy. This cross-sectional study of RH patients at Peking Union Medical College Hospital investigates the correlation between 24-hour urinary sodium excretion and office BP/HBPM control status to provide real-world clinical evidence for RH management.

This study was approved by the Peking Union Medical College Hospital Ethics Committee (ZS1377) and registered with the Chinese Clinical Trial Registry (ChiCTR1800017189).

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1. Subjects and Methods

1.1 Study Subjects and Grouping All RH patients treated at the Department of Cardiology, Peking Union Medical College Hospital from October 2017 to March 2018 were enrolled. RH was diagnosed according to Chinese guidelines: (1) aged 20-80 years; (2) failure to achieve BP control (<140/90 mmHg) despite

treatment with 3 antihypertensive drugs, including a diuretic, at optimal doses, while adhering to lifestyle modifications.

Exclusion criteria included: (1) secondary hypertension, renal insufficiency (eGFR<60 ml/(min · 1.73m²)), or poorly controlled diabetes (fasting glucose >11.0 mmol/L or HbA1c>8.0%); (2) use of medications affecting sodium absorption/excretion other than low-dose hydrochlorothiazide; (3) severe hepatic dysfunction, rheumatic disease, malignancy, pregnancy or lactation; (4) poor treatment compliance; (5) other conditions deemed unsuitable by investigators.

All patients provided informed consent. Patients were stratified into four groups based on quartiles of 24h-UNa: low 24h-UNa (<127.50 mmol), low-mid 24h-UNa (127.50-182.49 mmol), mid-high 24h-UNa (182.50-242.74 mmol), and high 24h-UNa (242.75 mmol).

1.2 Blood Pressure Measurement Methods 1.2.1 Office BP Measurement
Office BP was measured using calibrated upper-arm electronic sphygmomanometers with patients in seated position. Three measurements were taken and the mean of the two closest readings was recorded.

1.2.2 HBPM
Patients performed HBPM for one week, measuring BP in seated position on the right upper arm at four daily time points: before morning medication, 10 a.m., 4 p.m., and before bedtime. The mean of the two closest readings from each time point was used for analysis.

1.3 Assessment of Sodium Intake via 24-Hour Urine Sodium Patients received detailed written instructions for 24-hour urine collection. All urine samples were preserved, total volume recorded, and a mixed aliquot taken for analysis. Urinary sodium concentration was measured by ion-selective electrode method. Daily sodium intake was estimated using the formula: 24h-UNa (mmol) = sodium concentration (mmol/L) × 24-hour urine volume (L), assuming 99% of ingested sodium is excreted in urine and accounting for sodium' s proportion in NaCl.

1.4 General Clinical Data Collection Researchers measured height, weight, waist circumference, and calculated BMI. Fasting morning blood samples were collected for routine blood tests. eGFR was calculated using the CKD-EPI formula. Education level, medical history, and medication use were recorded.

1.5 Definitions of BP Control Status 1.5.1 Office BP Control
Defined according to 2010 Chinese Hypertension Guidelines: BP <140/90 mmHg for patients aged <65 years, and <150/90 mmHg for those 65 years; <130/80 mmHg for patients with proteinuria or diabetes.

1.5.2 HBPM Control
Defined as HBPM <135/85 mmHg.

1.6 Statistical Analysis SPSS 19.0 was used for statistical analysis. Normality of continuous variables was assessed. Normally distributed data were expressed as mean±SD, non-normally distributed data as median and interquartile range. Categorical data were expressed as absolute numbers and percentages. Differences in medication types and BP control rates across sodium levels were examined. P<0.05 was considered statistically significant.

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2. Results

2.1 General Characteristics and Urinary Sodium Levels A total of 202 patients were enrolled with mean age (59.87±16.30) years and mean 24h-UNa (198.92±96.59) mmol (estimated salt intake 11.64±5.65 g). Only 17.2% of patients met guideline recommendations (<6 g/day), while 82.8% exceeded 12 g/day and 15.1% exceeded 18 g/day.

Based on quartiles, patients were divided into four groups with mean urinary sodium levels from low to high: (92.35±22.79) mmol, (157.15±16.39) mmol, (212.32±15.16) mmol, and (333.91±72.61) mmol. With increasing urinary sodium levels, age decreased while BMI and waist circumference increased (P<0.001). The average number of antihypertensive medications also increased significantly (P<0.001), indicating that high urinary sodium patients were younger and more likely to have abdominal obesity.

2.2 Antihypertensive Drug Usage All subjects were taking 3 antihypertensive drugs including low-dose hydrochlorothiazide. The most commonly used drug classes were angiotensin-converting enzyme inhibitors/angiotensin receptor blockers (190/202, 94.0%), calcium channel blockers (178/202, 88.1%), -blockers (143/202, 70.8%), and aldosterone antagonists (63/202, 31.2%). Only 12 patients (5.9%) used -blockers. The number of antihypertensive drug classes increased progressively with rising urinary sodium levels.

2.3 BP Control Rates Across Different Urinary Sodium Levels No significant differences were observed in office BP control rates among the four urinary sodium groups (P=0.255). However, morning and 10 a.m. HBPM control rates differed significantly (P=0.040 and P=0.032, respectively), with the high urinary sodium group showing the lowest control rates. No significant differences were found for 4 p.m. or bedtime HBPM control rates.

2.4 Multivariate Analysis of Factors Affecting BP Control Status in RH Patients Multivariate logistic regression analysis was performed with office BP and HBPM control status as dependent variables, and BMI, eGFR,

24h-UNa, and number of drug classes as independent variables. Results showed 24h-UNa was independently associated with office BP control (OR=2.356, 95% CI 1.004-5.533, P=0.049), morning HBPM (OR=2.299, 95% CI 1.031-5.129, P=0.033), and 10 a.m. HBPM (OR=2.408, 95% CI 1.026-5.650, P=0.030), but not with 4 p.m. or nighttime HBPM control.

shows the general clinical characteristics of RH patients across urinary sodium quartiles.

[Figure 1: see original paper] illustrates the number of antihypertensive drug classes used across different urinary sodium levels.

[Figure 2: see original paper] shows HBPM control rates across different urinary sodium levels.

presents the multivariate logistic regression analysis of factors affecting office and home BP control status.

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3. Discussion

Assessment of sodium intake in RH patients is essential in clinical practice. This study demonstrates that RH patients commonly have excessive sodium intake, with 82.8% exceeding 12 g/day—significantly higher than the 6 g/day recommended by Chinese hypertension guidelines. High sodium intake may play an important role in poor BP control in this population.

International studies confirm that high sodium intake is a major environmental factor affecting BP. The INTERSALT study showed that for every 100 mmol increase in urinary sodium, systolic and diastolic BP increase by 3.5 mmHg and 1.5 mmHg, respectively. Chinese populations typically consume >12 g/day of salt. High sodium intake enhances renal sympathetic nerve function, increases plasma norepinephrine levels, and promotes sodium reabsorption in salt-sensitive patients. It also damages vascular endothelial function, reduces nitric oxide synthesis, and enhances resistance artery contractility.

Twenty-four-hour urinary sodium measurement is the most accurate method for assessing dietary sodium intake and has been used in major international epidemiological studies. While dietary recall and spot urine sodium methods are also used, they have limitations. In this cohort, all patients were on long-term low-dose hydrochlorothiazide, minimizing inter-individual differences in diuretic effects on urinary sodium measurements.

This study found that high sodium intake primarily affects BP control during stress states. Morning and 10 a.m. BP measurements, which reflect the stress response upon waking and during morning activities, showed stronger associations with sodium intake than afternoon or bedtime measurements. The increased catecholamine secretion and enhanced vascular reactivity to pressor

substances during morning sympathetic activation may contribute to BP fluctuations and poor control in RH patients. This provides mechanistic insight into how high sodium intake impairs BP control.

Limitations include the single-center design, relatively small sample size, and lack of salt sensitivity testing to differentiate effects in salt-sensitive versus salt-resistant patients. Additionally, the analysis considered only the number of antihypertensive drugs rather than specific drug types and dosages. Further large-scale studies are needed to validate these findings.

In conclusion, high sodium intake is prevalent among RH patients and is an independent risk factor for poor office BP and morning HBPM control. Sodium restriction is crucial for reducing BP fluctuations and improving control in this population.

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Note: Figure translations are in progress. See original paper for figures.