Aortic knob width is associated with non-dipping blood pressure pattern

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Abstract

Background: Aortic knob width (AKW) is the measurement of the radiographic configuration composed of the foreshortened aortic arch and a part of the descending aorta. We investigated the relationship between the non-dipper pattern and AKW.

Material and methods: All patients' office blood pressure measurements and 24-hour ambulatory blood pressure readings were recorded. A blood pressure drop of less than 10% was defined as non-dipping. The patients were grouped into Group 1; dipper pattern (37 patients; 22F, and mean age 49.2 ± 11.7 yrs) and Group 2; non-dipper pattern (64 patients; 37F, and mean age 53.7 ± 13.1 yrs). On posteroanterior chest radiography, the widest point of the aortic knob was measured along the straight imaginary line from the lateral edge of the trachea to the left lateral wall of the aortic arch.

Results: AKW was significantly higher in Group 2 compared to group 1 (36.7 ± 5.7 *vs.* 30.7 ± 4.5 mm, p < 0.001). The mean daytime and night-time systolic blood pressures, the mean night-time diastolic blood pressure levels, 24-hour mean blood pressure and mean pulse pressures were higher; percentage of nocturnal drops was significantly lower in Group 2 compared to Group 1. AKW was determined to be the parameter that was mostly related to the non-dipper pattern. A ROC analysis revealed that the area under the curve values for AKW values of non-dippers were 0.796 (95% CI: 0.707–0.884, p< 0.001).

Conclusion: AKW is significantly higher in non-dipper individuals compared to dippers. AKW values above 32.6 mm on the chest radiograph may be associated with non-dipper pattern especially in hypertensive individuals.

Key words: aortic knob width, non-dipper pattern, hypertension, chest radiography

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Introduction

Widespread hypertension is known risk factor for the development of cardiovascular disease, renal failure, and cerebrovascular disease [1]. Blood pressure exhibits a circadian rhythm in healthy individuals; starting to decrease later in the evening, reaching its lowest value at midnight, and rising just after waking up in the morning [2]. Drops ≥ 10% in mean systolic and diastolic blood pressure at night compared to the

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daytime values constitutes a dipping pattern, whereas reductions of less than 10% are known as non- dipping [3]. It is known that patients who are characterized by non-dipping (non-dippers) are at increased cardiovascular risk, target organ damage, and future cardiac and cerebral events [4].

Chest radiography is an inexpensive and easy method contributing to the diagnosis and treatment of several cardiovascular diseases. Aortic knob width (AKW) is the measurement of the radiographic configuration composed of the foreshortened aortic arch and a part of the descending aorta. It has been demonstrated in several studies that there is a relationship between AKW and various cardiovascular diseases in hypertensive patients [5–8].

We sought to investigate the relationship between the non-dipping pattern and AKW.

Material and methods

Patient selection

We enrolled a total of 101 consecutive patients (42 males, 59 females; mean age: 52.2 ± 13.1 years) without known hypertension and not receiving blood lowering drugs . Patients presented to our outpatient clinics of internal diseases and cardiology. underwent ambulatory blood pressure measurements either to confirm or rule out the HTN diagnosis. Detailed medical history (history of the complaints, medication use, previous blood pressure levels, etc.) was obtained from all participants and a detailed physical examination was performed. Diabetes was diagnosed when fasting blood glucose levels was above 125 or a patient was receiving antidiabetic treatment. Family history of heart disease was considered positive in patients with a history of cardiovascular disease in their first-degree relatives. Body mass index was calculated by dividing the body weight in kilograms by the square of body height in meters (kg/m^2) [9]. The waist and hip circumferences were measured with an elastic tape. The circumference of the waist was measured at the level of the umbilicus and the subcostal plane, while the patient stands in an upright position with both arms open.

We defined the metabolic syndrome (MetS) according to ATP-III criteria. MetS criteria include the presence of central obesity (waist circumference in men > 102 cm and women > 88 cm), hyperglycemia [fasting plasma glucose ≥ 100 mg/dL (5.6 mmol/L)], low HDL-C [HDL-C ≤ 40 mg/dL (1.03 mmol/L) in men and 50 mg/dL (1.29 mmol/L in women)], hypertriglyceridemia [fasting plasma triglycerides 150 mg/dL (1.7 mmol/L)] and arterial hypertension (peripheral arterial blood pressure ≥140/90 mm Hg). According to the ATP-III criteria MS was defined as the presence of three or more components [10].

Detailed information was provided for all patients included in the study and their informed consents were received. The study was approved by the local ethics committee with the ID number 2338.

Aortic knob width measurement

On posteroanterior chest radiography, the widest point of the aortic knob was measured along the straight imaginary line from the lateral edge of the trachea to the left lateral wall of the aortic arch. To minimize interpersonal differences, a single reviewer blinded to the participants' demographic data measured all AKW on chest radiography [11].

Blood pressure and laboratory measurement

Blood pressure was measured with a sphygmomanometer (ERKA perfect aneroid sphygmomanometer, Germany) and heart rate was recorded in sitting position after resting for 5 minutes. The participants were advised to avoid caffeinated drinks and exercise for at least 30 minutes before the measurement. Blood pressure was measured at left arm. During the measurement, each participant was seated with their tested arm supported at the level of the heart. The mean of 3 BP measurements was calculated and used in all analyses.

Hypertension is defined as office SBP values ≥ 140 mm Hg and/or diastolic BP (DBP) values ≥ 90 mm Hg according to European hypertension management guidelines [12] [13]. Subjects with pregnancy, history of obstructive sleep apnea, acute infection, acute vascular event, malignancy, secondary hypertension, chronic renal failure, and uncontrolled thyroid dysfunction were excluded, as were those with resistant hypertension and those using medications elevating blood pressure. Patients' fasting blood glucose, total cholesterol, low density lipoprotein (LDL), high density lipoprotein (HDL), triglyceride, thyroid function tests, urea, creatinine, aspartate aminotransferase (AST), alanine transaminase (ALT), sodium and potassium levels were measured from venous blood samples after 8 hours of fasting.

Ambulatory blood pressure monitoring (ABPM)

Twenty-four hour blood pressure monitoring was performed with a portable digital recorder

(BPlab Blood pressure monitor, BPLAB Standart, Schwalbach, Germany) and placing an appropriately sized cuff to left upper arm. The device was set to perform blood pressure measurements every 15 minutes during daytime and every 30 minutes between 00:00 at night and 08:00 in the morning. The patients were asked to continue their normal daily activities, to avoid heavy exercise, and to remain still during blood pressure measurements. The default setting for daytime (07:00 to 23:00) and night-time (23:00 to 07:00) hours were modified appropriately based on the patient's feedback. A night-time blood pressure drop of at least 10% was labeled as dipper pattern and a drop of less than 10% as non-dipper pattern [3].

Transthoracic echocardiography

Echocardiogram procedures were performed using a Philips EPIQ 7 device (Philips Healthcare, Andover, MA, USA). A 2.5 MHz probe was used for the Doppler measurements and a 2.5–3.5 MHz probe was used for tissue Doppler measurements. Left ventricle (LV) dimensions and wall thickness were obtained from the parasternal long axis with an M-mode cursor positioned just beyond the mitral leaflet tips, perpendicular to the long axis of the ventricle. LV end-diastolic diameter and end-systolic diameter and thicknesses of the interventricular septum and posterior wall of the left ventricle were measured. LV ejection fraction (LVEF) was estimated by Simpson's rule. Mitral inflow velocities were evaluated by pulse-wave Doppler with the sample volume placed at the tip of the mitral leaflets from the apical 4-chamber view. Diastolic peak early (E), peak late transmitral flow velocity (A), and deceleration time of peak E velocity (EDT) were measured. Tissue Doppler velocities (Sm, Em, Am) were measured from lateral, septal and tricuspid annuli [14]. Measurements were calculated from 3 cardiac cycles.

Statistical analysis

The study data were analyzed using SPSS 22.0 software package. The numerical variables were expressed as mean ± standard deviation and non-normal distributed variables with median. Categoric variables were expressed as frequency (n) and percentage (%). Inter-group differences for categoric variables were tested using χ^2 test or, when the assumptions for χ^2 test were unmet, Fisher's exact test. The normality of distribution of numerical variables was tested with Kolmogorov-Smirnov test. The comparison of continuous variables between two independent groups was performed with independent samples t test when the parametric test assumptions were met, and with Mann Whitney-U test when the parametric test assumptions were unmet. Spearman correlation analysis was used to evaluate the relationship between AKW and ABPM measurements. To assess the independent contribution of each variable, except for ambulatory blood pressure parameters, we performed a multiple logistic regression analysis that included all clinical variables with a $p < 0.05$ in the univariate analysis. The odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. A receiver operating characteristic (ROC) curve analysis was used to calculate the AKW value that predicted non-dippers with the best specificity and sensitivity. A p value of less than 0.05 was considered statistically significant.

Results

Using the data obtained via ambulatory blood pressure monitoring (ABPM); the study population was divided into 2 groups as follows: Group 1; dipper pattern, 37 patients, 22 females, and mean age 49.2 ± 11.7 years and Group 2; non-dipper pattern, 64 patients, 37 females, and mean age 53.7 ± 13.1 years. Table 1 shows the comparison of demographic data, laboratory findings, and office blood pressure measurement results between the groups. Systolic and diastolic blood pressure levels were significantly higher in Group 2 compared to Group 1 (Tab. 1). The frequencies of hypertension and MetS were significantly higher in Group 2 compared to Group 1 (Tab. 1). The measured values of AKW were significantly higher in Group 2 compared to Group 1 (36.7 ± 5.7 *vs.* 30.7 ± 4.5 mm, p < 0.001).

ABPM records are shown in Table 2. The mean daytime and night-time systolic blood pressure and the mean night-time diastolic blood pressure levels were higher in Group 2 compared to Group 1. The percentage of nocturnal drops was significantly lower in Group 2 compared to Group 1. The 24-hour mean blood pressure and mean pulse pressure were higher in Group 2 compared to Group 1.

Positive correlations were found between AKW and age, the mean daytime systolic and diastolic blood pressure levels, the night-time maximum systolic and diastolic blood pressure levels, the mean night-time systolic and diastolic blood pres-

Table 1. Demographic and laboratory features of the groups

	Group 1 (n = 37)	Group 2 (n = 64)	p
Age [years]	49.2 ± 11.7	53.7 ± 13.1	0.09
Gender [F, n]	22	37	0.87
BMI [kg/m^2]	30.9 ± 9.6	29.9 ± 5.4	0.46
Systolic blood pressure [mm Hg]	137.0 ± 15.1	147.2 ± 12.8	< 0.001
Diastolic blood pressure [mm Hg]	80.9 ± 10.9	74.1 ± 11.8	0.02
Heart rate [beats/min]	82.8 ± 9.5	80.8 ± 11.9	0.38
Hypertension [n]	21	45	0.008
Diabetes Mellitus [n]	7	15	0.57
Family history of CAD [n]	16	25	0.72
Smoking [n]	12	21	0.96
Metabolic syndrome [n]	8	28	0.02
Obesity [n]	14	30	0.33
Glucose [mg/dL]	107.5 ± 41.7	113.1 ± 51.1	0.59
Total cholesterol [mg/dL]	196.2 ± 64.8	185.9 ± 75.5	0.52
Triglyceride [mg/dL]	185.9 ± 75.5	203.7 ± 133.9	0.50
HDL [mg/dL]	43.5 ± 8.5	46.4 ± 9.9	0.17
LDL [mg/dL]	134.8 ± 40.6	135.9 ± 33.2	0.89

BMI — body mass index; CAD — coronary artery disease; HDL — high density lipoprotein; LDL — low density lipoprotein

Table 2. Comparison of ambulatory blood pressure measurements between the groups

	Group 1 (n = 37)	Group 2 (n = 64)	p
Mean daytime systolic BP [mm Hg]	124.7 ± 12.3	131.6 ± 15.5	< 0.03
Mean daytime diastolic BP [mm Hg]	80.3 ± 8.2	80.5 ± 10.0	< 0.91
Mean night systolic BP [mm Hg]	109.1 ± 10.7	128.0 ± 16.5	<0.001
Mean night diastolic BP [mm Hg]	68.0 ± 7.9	77.1 ± 10.2	< 0.001
24 hour mean systolic BP [mm Hg]	118.1 ± 9.6	128.8 ± 14.1	0.01
24 hour mean diastolic BP [mm Hg]	75.1 ± 5.9	79.5 ± 9.6	0.07
24 hour mean BP [mm Hg]	92.5 ± 11.2	99.0 ± 11.7	0.01
% nocturnal decrease systolic [mm Hg]	14.3 ± 4.9	4.6 ± 5.3	< 0.001
% nocturnal decrease diastolic [mm Hg]	13.5 ± 3.8	3.3 ± 5.6	< 0.001
Mean pulse pressure [mm Hg]	43.2 ± 7.8	48.2 ± 10.3	0.03

BP — blood pressure

sure levels, the mean 24-hour systolic and the mean blood pressure levels (Tab. 3). Similarly, there was a negative correlation between AKW and nocturnal drops in the systolic and diastolic blood pressure levels (Tab. 3). Of the echocardiographic parameters, the interventricular septum thickness and the aortic root diameter were significantly correlated ($r = 0.51$, $p < 0.001$; $r = 0.44$, $p = 0.001$, respectively). Also, there was a significant and positive correlation between AKW and age ($r = 0.50$, $p < 0.001$).

In order to study which parameter was associated with the non-dipper pattern; modelled univariate and multivariate regression analyses were applied, using the model which was created with the inclusion of AKW, age, gender, presence of hypertension, BMI, waist-height ratio, and the presence of MetS. AKW was determined to be the parameter that was most related to the non-dipper pattern (Tab. 4). A ROC analysis revealed that the area under the curve values for AKW values of non-dippers were 0.796

Table 3. Pearson's correlation analysis between the aortic knob width (AKW) and several ambulatory blood pressure monitoring (ABPM) recording parameters

	rho	p
Daytime mean systolic BP	0.32	0.003
Daytime mean diastolic BP	0.22	0.047
Night-time mean systolic BP	0.48	< 0.001
Night-time mean diastolic BP	0.40	< 0.001
% nocturnal decrease systolic	20.39	< 0.001
% nocturnal decrease diastolic	–0.38	< 0.001
24 hour mean systolic BP	0.41	0.007
24 hour mean diastolic BP	0.25	0.101
24 hour mean BP	0.33	0.02

BP — blood pressure

(95% CI: 0.707–0.884, p < 0.001) (Fig. 1). The cut-off value for AKW to predict non-dippers was 32.6 mm with a sensitivity of 71.9% and a specificity of 75.7%.

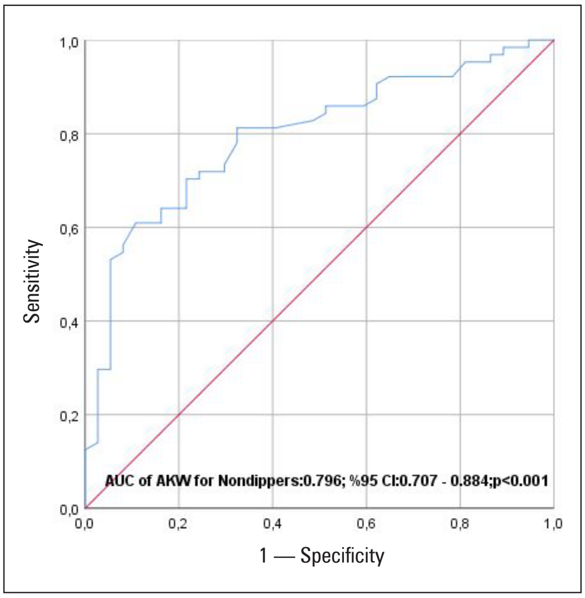

Figure 1. Receiver operating characteristics (ROC) curve used to calculate the aortic knob width (AKW) value that predicted non-dippers

Discussion

The main finding of our study is that AKW is associated with the non-dipper pattern in both hypertensive and non-hypertensive individuals. AKW correlates with blood pressure parameters obtained via ABPM.

In routine clinical practice, chest radiograms are obtained in the majority of cardiac patients. Information about many diseases and conditions can be obtained via chest radiographs. Elderly patients are known to have more dilated and tortuous aortas. Aneurysmal dilatation of the aorta or of the aortic arch can be observed with persistent high blood pressure [15]. Several studies are available, associating AKW with various cardiovascular disorders and hypertension.

In a 374 patient study, the relationship of AKW with subclinical atherosclerosis was investigated in hypertensive patients by using the cardio-ankle vascular index (CAVI) as a marker of subclinical atherosclerosis. The study demonstrated that AKW over 41 mm can predict subclinical atherosclerosis [7].

In a similar study that investigated the relationship between the carotid intima media thickness (CIMT) and AKW in patients with essential hypertension, Erkan et al. found a strong correlation between those two variables (r = 0.62, p < 0.001). By applying regression analysis, they also showed

Table 4. Univariate and multivariate regression analysis showing the parameters related with non-dipper pattern

	OR	Univariate		Multivariate	
		95% CI	p OR	95% CI	p
AKW	9.329	3.384–25.715	< 0.001 6.848	1.479–31.698	0.014
Metabolic syndrome	2.819	1.117–7.114	0.028		
Hypertension	3.109	1.338–7.222	0.008		
Waist to length ratio	2.729	1.168–6.380	0.020		
Gender	1.070	0.470–2.437	0.871		
Body mass index	1.561	1.050–2.320	0.028		
Age	1.029	0.996–1.064	0.088		

OR — odds ratio; CI — confidence interval that AKW was one of the independent predictors to predict CIMT [6].

Sung et al. have conducted a study on 587 individuals to investigate whether there is a relationship between AKW and heart rate variability, which is used for the evaluation of the autonomic nervous system activity and which is recorded with an ambulatory Holter rhythm device. The study found that AKW was significantly associated with the values of the time domain, one of the parameters indicating heart rate variability. Considering the lack of association of AKW with the frequency domain values and with some other parameters in women participants as the limitations of that study, the investigators showed that AKW was associated with heart rate variability parameters [16]. Because the main purpose of our study was to analyze the relationship between blood pressure patterns and AKW, variables of heart rate variability have not been investigated. However, the study by Sung et al. appears valuable by showing the relationship of AKW with the autonomic nervous system as well as the cardiovascular system.

Rayner et al. compared chest radiographs from 82 hypertensive and 77 normotensive patients. In their study, they not only found that AKW was larger in hypertensive patients compared to normotensive individuals but also demonstrated that AKW was correlated with age and systolic and diastolic blood pressure levels. In our study; the categorization of the patients as normotensive and hypertensive individuals revealed that AKW was significantly larger in hypertensive individuals compared to normotensive ones (36.4 ± 5.9 mm compared to 31.7 ± 5.1 mm, respectively; $p < 0.001$) [5].

Jeon et al. included 252 patients in a study investigating whether there was a relationship between the aortic pulse pressure (APP) and AKW. Besides finding larger AKW in patients with high APP, they also demonstrated a positive correlation between those two variables. Although the correlation they found in their study was weak ($r = 0.207$, $p < 0.001$); in the linear regression analysis, they showed a significant relationship between APP and AKW [17].

Sevencan et al. showed that when combined with renal resistive index, AKW could be a diagnostic and prognostic predictor of renal pathologies in individuals with essential hypertension [18].

In a study conducted by Gurbak et al. on 144 patients, the relationship between AKW and left ventricular hypertrophy was investigated in hypertensive patients. The investigators showed that an AKW of larger than 37 mm could predict left ventricular hypertrophy with high sensitivity and specificity [8]. In our study, AKW showed a significant correlation with the interventricular septum and aortic root diameter measured with transthoracic echocardiography.

Our study is a cross-sectional study; which included a population undergoing ABPM in a specific period. In our study, the diagnosis of hypertension was made or ruled out according to the ABPM results. The diameter of AKW in non-dipper individuals was found to be higher than that of dipper individuals and it was demonstrated that AKW values correlated with ABPM parameters in our study. The regression analysis is suggestive that AKW values of larger than 32.6 mm on the chest radiography would be associated with non-dipping blood pressures with 71.9% sensitivity and 75.7% specificity. To the best of our knowledge, our study is the first in associating AKW with blood pressure patterns.

In a large-scale study conducted in Korea, the relationship between AKW and MetS was investigated and it was shown that AKW was not only correlated with the MetS criteria but also increased as the number of metabolic syndrome components increased [10]. In our study; the rate of MS was significantly high in the group of individuals with a non-dipping blood pressure pattern, however, AKW was correlated only with the systolic blood pressure component of MetS. We think that the small number of individuals with MetS in our study population caused this result.

Conclusions

Being a simple and relatively inexpensive method AKW can modestly differentiate non-dipper individuals from dippers. AKW values above 32.6 mm warrants evaluation of the diurnal blood pressure profile.

Limitations of the study

Our study's major limitation is the small population size in the study groups. This study was a cross-sectional study and included patients meeting the inclusion criteria during a certain period. Even though the measurement of AKW is individual-based, a blinded researcher performed the measurements in our study in order to reduce both the error margin and the bias in the measured results.

Conflict of interest

The authors declare that they have no conflict of interest.

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