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Hypertension

A Novel Marker of Impaired Aortic Elasticity in Never Treated Hypertensive Patients: Monocyte/High-Density Lipoprotein Cholesterol Ratio

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Background: Monocyte to high density lipoprotein cholesterol ratio (MHR) is generally understood to be a candidate marker of inflammation and oxidative stress. Therefore, we aimed to assess the association between MHR and aortic elastic properties in hypertensive patients.

Methods: A total of 114 newly-diagnosed untreated patients with hypertension and 71 healthy subjects were enrolled. Aortic stiffness index, aortic strain and aortic distensibility were measured by using echocardiography.

Results: Patients with hypertension had a significantly higher MHR compared to the control group ($p < 0.001$). Also, aortic stiffness index ($p < 0.001$) was significantly higher and aortic distensibility ($p < 0.001$) was lower in the hypertensive group. There was a positive correlation of MHR with aortic stiffness index ($r = 0.294$, $p < 0.001$) and negative correlation with aortic distensibility ($r = -0.281$, $p < 0.001$). In addition, MHR and high sensitivity C-reactive protein have a positive correlation ($r = 0.30$, $p < 0.001$). Furthermore, MHR was found to be an independent predictor of aortic distensibility and aortic stiffness index.

Conclusions: In patients with newly-diagnosed untreated essential hypertension, higher MHR was significantly associated with impaired aortic elastic properties.

Key Words: Aortic stiffness • Hypertension • Inflammation • Oxidative stress

INTRODUCTION

Aortic stiffness is a strong independent predictor of cardiovascular morbidity and mortality in hypertension (HT).[1] Hypertension is one of the most substantial pathologies causing impaired arterial elasticity regardless of patient age.[2] Inflammation and oxidative stress are the cornerstones for cardiovascular events both in healthy and hypertensive subjects.[3,4] Both mechanisms play a central role in the development and progression of hypertensive disease, by the help of cellular components including monocytes and macrophages. Additionally, high-density lipoprotein cholesterol (HDL-C) has inhibitory effects on inflammatory and oxidative processes in addition to anti-atherosclerotic efficacy.[5] Low HDL-C is a strong and independent predictor of cardiovascular disease and aortic stiffness.[6] Because of such unfavorable effects of monocytosis and low HDL-C, the monocyte to HDL-C ratio (MHR) has been found to be a new prognostic indicator in chronic kidney disease[7] and cardiac disorders.[8-10] As yet, no study has examined whether MHR would be linked with aortic stiffness in

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patients with essential HT. Although, the association of MHR with inflammatory biomarkers like high-sensitivity C-reactive protein (hs-CRP) has been reported previously in patients with slow coronary flow,[11] the presence of such an association in hypertensive patients was unclear. Therefore, we aimed to evaluate the relationship between MHR and aortic elastic properties by using transthoracic echocardiography (TTE) in association with the inflammatory markers such as hs-CRP in patients with newly-diagnosed and never-treated essential HT.

MATERIALS AND METHODS

Study population

In this study, a total of 114 patients with newly-diagnosed and untreated essential HT (48.2% male; age: 52.5 ± 5.4 years) and 71 healthy control subjects (53.5% male; age: 52.8 ± 9.4 years) were consecutively enrolled, and all participants were Caucasian. We have performed a retrospective analysis of prospectively collected data. Patients were enrolled into the present study through our cardiology department between March 2013-June 2014.

Blood pressure was measured from the brachial artery with an external mercury sphygmomanometer while the patient is seated in a chair for at least 5 min and was noted. Hypertension was defined as systolic blood pressure (SBP) of ≥ 140 mmHg and/or a diastolic blood pressure (DBP) of ≥ 90 mmHg (mean of three measurements, at least two visits).[12] The healthy control subjects had been admitted for check-up, with no cardiovascular or any other organ system disease and with normal physical examination, chest X-ray, electrocardiography, and 2-dimensional and Doppler echocardiography. Patients with secondary hypertension, renal failure, diabetes, heart failure, valvular heart disease, coronary artery disease, malignancy, active infectious/inflammatory disease, chronic obstructive pulmonary disease and arrhythmia-like atrial fibrillation and the presence of use of any antihypertensive medication were excluded from the study. Eleven participants with poor echocardiographic image quality were also excluded before study enrollment. Demographic characteristics including age, gender, smoking status and body mass index (BMI) were noted. This study was consistent with the Declaration of Helsinki, and approved by the Institutional Ethics Committee, with informed consent obtained from all participants.

Transthoracic echocardiography

Echocardiographic examination was performed with the assistance of VIVID 7 Dimension Cardiovascular Ultrasound System (Vingmed-General Electric, Horten, Norway) with a 3.5 MHz transducer. All measurements were calculated according to the criteria proposed by the American Society of Echocardiography.[13,14] Echocardiographic examination was performed in the left lateral decubitus position. Parasternal long- and short-axis views and apical views were used as standard imaging windows. All echocardiographic images were analyzed by an experienced cardiologist who were blinded to the characteristics of the study participants. All echocardiographic images included at least 3 consecutive beats and they were digitally stored for further analysis.

Determining the elastic properties of the aorta

Echocardiographic evaluation started with determination of the elastic properties of the aorta. To this end, the ascending aorta was evaluated at 3 cm above the aortic annular plane in the parasternal long-axis view and measurements were carried out with M-mode recordings. The systolic and diastolic diameters of the aorta were measured between the lower edge of the upper wall and the upper edge of the lower wall.[15] Aortic stiffness was based on the relationship between changes in aortic diameter and blood pressure with each cardiac pulse. Systolic diameter (SD) was measured as the maximal diameter of aorta during systole, and diastolic diameter (DD) was the minimal diameter of aorta measured at the peak of the QRS complex of the simultaneously recorded electrocardiogram. Three consecutive cardiac beats were measured routinely, and the average of these three values was calculated. The BP was measured from the right brachial artery with an external sphygmomanometer simultaneous with echocardiographic recordings. Afterwards, the following aortic elastic parameters were calculated, where "Ln" is the natural logarithm:[16]

$$\text{Aortic strain} = (SD - DD)/DD$$

$$\text{Aortic distensibility (AoD)} = 2 \times (SD - DD)/[(SBP - DBP) \times DD] \times 10^{-6}\ cm^2/dyn$$

Aortic stiffness index (β) = Ln (SBP/DBP)/[(SD – DD)/DD]

To determine the reproducibility of systolic and diastolic dimension measurements, 10 samples were randomly selected and measurements were performed at different times by the same echocardiographer to define intraobserver variability, and by two different echocardiographers to define interobserver variability. Overall, it was determined that the reproducibility was excellent. The correlation coefficient was 0.952 ($p < 0.001$) for intraobserver variability and 0.944 ($p < 0.001$) for interobserver variability.

Laboratory measurements

Blood samples were taken from the antecubital vein after 12 hours of fasting in the morning. HDL-C was measured using enzymatic calorimetric kits with intra- and interassay coefficients of variation (CV) of < 10% (Roche Diagnostics GmbH, Mannheim, Germany). Blood samples were subsequently placed into tubes containing ethylenediaminetetraacetic acid (EDTA). The types of blood cells was determined by an automated blood count device (Beckman Coulter AU 2700 Plus) by the method of electrical impedance. The serum hs-CRP level was measured by nephelometric assay (Behring Diagnostic Marburg, Germany)

Statistical analysis

Analyses were performed using the Statistical Package for the Social Sciences (SPSS) software version 20.0 for Windows (SPSS Inc, Chicago, IL, USA). The Kolmogorov-Smirnov test was used to test the normalcy of distribution of continuous variables. Continuous variables were defined as means ± standard deviation or median [interquartile range (IQR)] and categorical variables were given as n (%). The independent sample t-test or the Mann-Whitney U test was used for the comparison of the continuous variables and the chi-square test was used for the comparison of categorical variables. Spearman's test was used for correlation analysis. The study group was further categorized into 2 subgroups as median MHR < 18.3 and ≥ 18.3 for comparison of demographic, clinical and laboratory parameters. The unadjusted associations of MHR with aortic elastic parameters may have been confounded by demographic variables and clinical characteristics, which are important determinants of arterial properties. Therefore, we applied standard multiple linear regression analyses with aortic strain, aortic stiffness index and aortic distensibility as dependent variables and MHR as an independent variable. Entry into the multivariate regression model required a p value of < 0.10 with the univariate regression model. Statistical significance was defined as $p < 0.05$.

RESULTS

Among baseline characteristics, low-density lipoprotein cholesterol (LDL-C) ($p < 0.001$), triglyceride ($p < 0.001$), hs-CRP levels ($p < 0.001$) and white blood cell counts ($p < 0.001$) were significantly higher in the hypertension group. Baseline characteristics of the study population are shown in Table 1. Additionally, MHR was significantly higher in the hypertensive group as compared to the control group [21.7 (IQR: 16.9-24.9) vs. 14.5 (IQR: 12.1-17.2); $p < 0.001$] (Figure 1).

Among aortic elasticity parameters, the β index was significantly higher in the HT group [12.6 (IQR: 7.2-18.1) vs. 7.1 (IQR: 5.4-8.6); $p < 0.001$], whereas AoD was lower in the HT group as compared to the control group (3.0 ± 1.5 vs. 4.8 ± 1.3, $p < 0.001$) (Table 1).

When the study population was categorized into 2 subgroups with median MHR < 18.3 and ≥ 18.3, the rate of HT was higher in patients with median MHR > 18.3 [34 (36.6%) vs. 80 (87%), $p < 0.001$]. In addition, white blood cell count [8548 (IQR: 7731-9223) vs. 7055 (IQR: 6341-8403), $p < 0.001$] and hs-CRP level [2.41 (IQR: 1.90-2.86) vs. 1.62 (IQR: 1.33-1.87), $p < 0.001$] were significantly increased in patients with median MHR ≥ 18.3 (Table 2).

In correlation analysis, the MHR was positively correlated with β index ($r = 0.294$, $p < 0.001$) (Figure 2) and hs-CRP ($r = 0.3$, $p < 0.001$) (Figure 3) and negatively correlated with AoD (0.281, $p < 0.001$) (Figure 2). But, there was no correlation between pulse pressure and MHR ($r = -0.032$, $p = 0.66$). The association of aortic elastic parameters with the clinical and laboratory parameters evaluated in univariate and stepwise multivariate linear regression analysis was shown in Table 3. hs-CRP level was found to be an independent predictor of aortic st-

Table 1. Baseline clinical, laboratory and echocardiographic data of the study population according to presence of hypertension (n = 185)

Variables	Hypertensive group (n = 114)	Control group (n = 71)	p value
Clinical parameters			
Age, years	52.5 ± 5.4	52.8 ± 9.4	0.84
Male gender, n (%)	55 (48.2)	38 (53.5)	0.55
Smoking, n (%)	32 (28.1)	21 (29.6)	0.87
Body mass index, kg/m^2	25.0 ± 4.7	23.9 ± 3.8	0.10
Systolic BP, mmHg	142.2 ± 13.9	130.1 ± 13.8	< 0.001
Diastolic BP, mmHg	91.3 ± 7.5	79.5 ± 10.5	< 0.001
Laboratory parameters			
Hemoglobin, g/dl	13.8 ± 3.8	14.3 ± 3.5	0.44
Platelets, 10^3/mm^3	278.9 ± 59.7	276.9 ± 65.4	0.84
White blood cell, 10^3/mm^3	8808 (IQR: 7992-9542)	6468 (IQR: 5933-7055)	< 0.001
Monocyte count, 10^3/mm^3	876.7 ± 140.8	653.2 ± 103.3	< 0.001
Fasting plasma glucose, mg/dl	95.6 ± 4.1	95.8 ± 4.5	0.79
Creatinine, mg/dl	0.77 (IQR: 0.65-0.89)	0.74 (IQR: 0.60-0.86)	0.12
Total cholesterol, mg/dl	199.8 ± 26.2	195.6 ± 21.9	0.27
HDL cholesterol, mg/dl	41.8 ± 8.3	45.3 ± 11.6	0.02
LDL cholesterol, mg/dl	145.8 (IQR: 138-154)	136.8 (IQR: 129-141)	< 0.001
Triglyceride, mg/dl	134.6 ± 14.9	126.3 ± 15.5	< 0.001
Monocyte/HDL cholesterol ratio	21.7 (IQR: 16.9-24.9)	14.5 (IQR: 12.1-17.2)	< 0.001
hs-CRP, mg/L	2.41 (IQR: 1.90-2.86)	1.62 (IQR: 1.33-1.87)	< 0.001
Echocardiographic parameters			
LVEF, %	65.8 ± 7.4	66.0 ± 10.1	0.87
Aortic strain, %	6.8 ± 3.8	7.8 ± 3.9	0.10
Aortic stiffness (β) index	12.6 (IQR: 7.2-18.1)	7.1 (IQR: 5.4-8.6)	< 0.001
Aortic distensibility, cm^2·dyn^{-1}·10^{-6}	3.0 ± 1.5	4.8 ± 1.3	< 0.001

Data are means ± S.D., median (IQR) or n (%).
BP, blood pressure; HDL, high density lipoprotein; hs-CRP, high sensitive C-reactive protein; IQR, interquartile range; LDL, low density lipoprotein; LVEF, left ventricular ejection fraction.

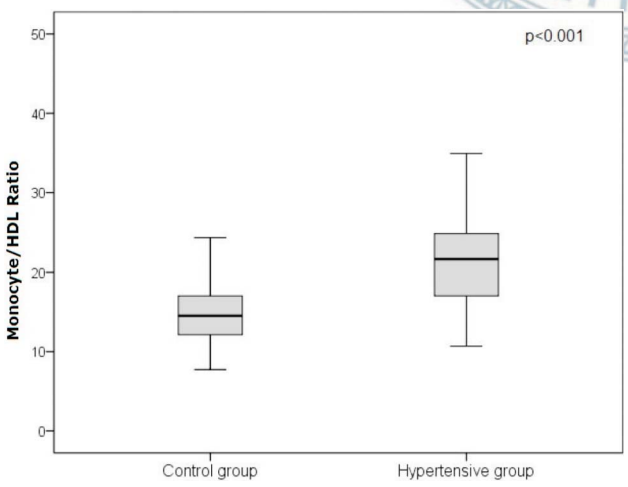

Figure 1. *The comparison of monocyte to high-density lipoprotein cholesterol ratio between hypertensive and control groups (p < 0.001).*

rain (p < 0.02). Additionally, the MHR was also found to be an independent predictor of both AoD (p < 0.02) and β index (p < 0.01).

DISCUSSION

Our study results showed that 1) the MHR was significantly higher in the newly-diagnosed and never-treated hypertensive patients compared to the healthy control group, 2) the MHR was positively correlated with hs-CRP, and 3) the MHR was significantly associated with β index and AoD, and found to be an independent predictor for β index and AoD.

Aortic stiffness is associated with several cardiovas-

Table 2. Baseline clinical, laboratory and echocardiographic data of the study population according to the median monocyte/HDL cholesterol ratio of < 18.30 and ≥ 18.30 (n = 185)

Variables	Monocyte/HDL cholesterol Ratio		p value
	< 18.30 (n = 93)	≥ 18.30 (n = 92)	
Clinical parameters			
Age, years	52.4 ± 8.2	52.8 ± 6.0	0.70
Male gender, n (%)	45 (48.3)	48 (52.2)	0.56
Smoking, n (%)	23 (24.7)	30 (32.6)	0.26
Body mass index, kg/m^2	24.7 ± 4.6	24.5 ± 4.3	0.83
Hypertension, n (%)	34 (36.6%)	80 (87%)	< 0.001
Systolic BP, mmHg	122.9 ± 14.3	139.7 ± 15.8	0.001
Diastolic BP, mmHg	76.5 ± 8.5	92.1 ± 11.5	< 0.001
Laboratory parameters			
Hemoglobin, g/dl	14.1 ± 3.5	13.8 ± 3.9	0.60
Platelets, $10^3/mm^3$	280.1 ± 67.3	276.0 ± 55.8	0.65
White blood cell, $10^3/mm^3$	7055 (IQR: 6341-8403)	8548 (IQR: 7731-9223)	< 0.001
Monocyte count, $10^3/mm^3$	684.5 ± 118.2	898.5 ± 139.4	< 0.001
Fasting plasma glucose, mg/dl	95.6 ± 4.3	95.8 ± 4.2	0.86
Serum creatinine, mg/dl	0.74 (IQR: 0.61-0.85)	0.76 (IQR: 0.64-0.94)	0.09
Total cholesterol, mg/dl	199.9 ± 20.5	196.4 ± 28.4	0.34
HDL cholesterol, mg/dl	48.9 ± 8.4	37.3 ± 7.4	0.02
LDL cholesterol, mg/dl	139.1 (IQR: 132-145)	143.4 (IQR: 137-152)	0.001
Triglyceride, mg/dl	130.0 ± 15.4	132.9 ± 15.8	0.21
Monocyte/HDL cholesterol ratio	14.6 (IQR: 12.4-16.2)	23.5 (IQR: 21.5-27.2)	< 0.001
hs-CRP, mg/L	1.81 (IQR: 1.24-2.23)	2.38 (IQR: 1.71-2.69)	< 0.001
Echocardiographic parameters			
LVEF, %	65.5 ± 9.7	66.2 ± 7.3	0.59
Aortic strain, %	7.7 ± 3.9	6.6 ± 3.7	0.05
Aortic stiffness (β) index	7.9 (IQR: 5.5-11.3)	11.9 (IQR: 6.6-18.0)	< 0.001
Aortic distensibility, $cm^2 \cdot dyn^{-1} \cdot 10^{-6}$	4.2 ± 1.61	3.2 ± 1.65	< 0.001

Data are means ± S.D., median (IQR) or n (%).
BP, blood pressure; HDL, high density lipoprotein; hs-CRP, high sensitive C-reactive protein; IQR, interquartile range; LDL, low density lipoprotein; LVEF, left ventricular ejection fraction.

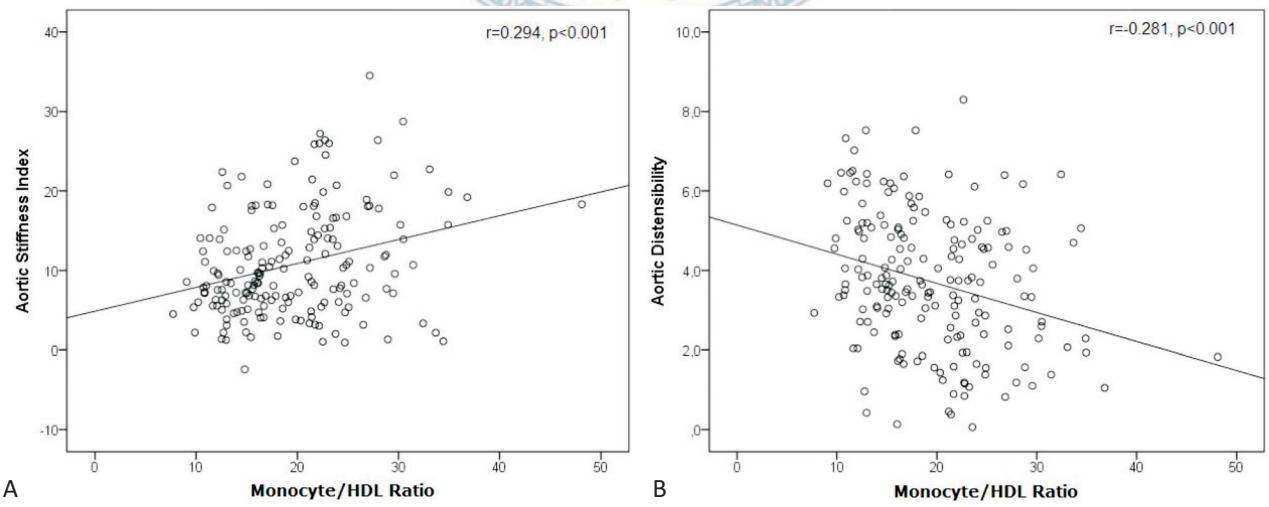

Figure 2. *The correlation of monocyte to high-density lipoprotein cholesterol ratio with aortic stiffness index (A) and aortic distensibility (B).*

cular conditions which have a close relationship with inflammation such as atherosclerosis,[17,18] carotid intima-media thickening,[19] coronary events,[20] and end-stage renal disease.[21] Increased arterial stiffness can be an early manifestation of subclinical atherosclerosis and vascular structural modifications owing to arterial hypertension, besides its potential etiological effect in cardiovascular disease.[22] Previous studies have shown that hs-CRP as an acute phase protein predicted adverse outcome in patients with cardiovascular disease and in sight-healthy individuals.[23] Endothelial dysfunction and the inflammatory process in the vascular wall play an important role in the etiology and target organ damage of hypertension.[24] Monocytes as a subgroup of leukocytes play a central role in this inflammatory process.[25] The association between inflammatory cytokines and hypertension has been shown in animal models and in human studies.[26] Vanhala et al.[26] reported that there was an association of both the interleukin-1 beta and the interleukin 1-receptor antagonist with blood pressure levels and development of hypertension in a prospective study. Increased arterial stiffness is a part of angiotensin II-induced vascular injury in humans and is closely associated with inflammation.[27] Various chemokines included in the pathogenesis of hypertension like monocyte chemoattractant protein-1 (MCP-1; CCL2), interferon-inducible protein (IP-10; CXCL10), interleukin-8 (IL-8; CXCL8), RANTES (CCL5), fractalkine (CX3CL1) and their receptors (CCR2, CCR5, CXCR1, CXCR2, CXCR3 and CX3CR1). These proteins cause the migration of monocytes into the vascular wall, subsequent endothelial dysfunction, impact on nitric oxide and endothelin-1 and smooth muscle cell proliferation.[28] It has been demonstrated that monocyte count was an independent and significant predictor of plaque formation and progression in atherosclerosis.[29] The evidence also suggests that high HDL-C was associated with a reduced risk for cardiovascular adverse out-

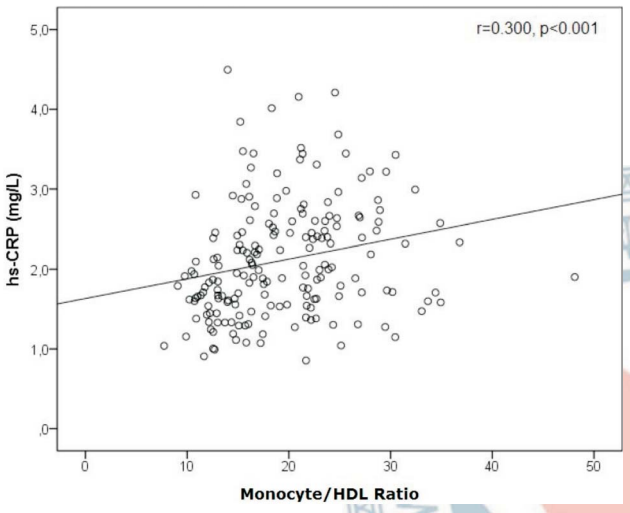

Figure 3. *The association of hs-CRP with monocyte to high-density lipoprotein cholesterol ratio.*

Table 3. Univariate and stepwise multivariate linear regression analysis of aortic elasticity parameters in patients with essential hypertension

Variables	Aortic strain				Aortic distensibility				Aortic stiffness index			
	Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate	
	β	p	β	p	β	p	β	p	β	p	β	p
Age	-0.048	0.52	-	-	0.085	0.25	-	-	0.114	0.12	-	-
BMI	0.047	0.52	-	-	-0.060	0.42			0.034	0.65	-	-
Smoking	0.029	0.69	-	-	-0.013	0.86			-0.008	0.91	-	-
Office SBP	-0.064	0.39	-	-	-0.215	0.003	-0.071	0.33	0.109	0.14	-	-
Office DBP	-0.057	0.44	-	-	-0.140	0.06	-0.081	0.24	0.014	0.85	-	-
Pulse pressure	0.025	0.73	-	-	-0.034	0.64	-	-	-0.001	0.99	-	-
WBC	-0.076	0.30			-0.374	< 0.001	-0.315	< 0.001	0.361	< 0.001	0.277	0.001
Monocyte/HDL ratio	-0.141	0.04	-0.038	0.97	-0.281	< 0.001	-0.172	0.02	0.294	< 0.001	0.187	0.01
LDL cholesterol	0.015	0.84	-	-	-0.257	< 0.001	-0.106	0.16	0.234	0.001	0.085	0.26
Triglyceride	-0.043	0.56	-	-	-0.090	0.23			0.110	0.14	-	-
hs-CRP	-0.172	0.02	-0.172	0.02	-0.236	0.001	-0.71	0.34	0.132	0.07	0.039	0.59

BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; hs-CRP, high sensitive C-reactive protein; SBP, systolic blood pressure; WBC, white blood cell count.

comes. The anti-atherosclerotic specifications of HDL-C have been mainly directed to its activity in the reverse cholesterol transport system. Previous studies have also demonstrated that an increase in the serum HDL-C level is an independent predictor of coronary plaque recession.[30] Tani et al.[31] showed that both a reduction in the peripheral blood monocyte count and increment in the serum HDL-C level plays a preventive role in the progression of atherosclerosis. Kanbay et al.[7] showed that MHR as an indicator for inflammation and oxidative stress was significantly associated with worse cardiovascular outcome in predialytic chronic kidney disease patients. In a recent study, Canpolat et al.[11] reported that higher MHR indicating enhanced inflammation and oxidative stress has been significantly and independently associated with the presence of slow coronary flow. Such a link between increased MHR and enhanced inflammation and oxidative stress was also shown by Canpolat et al.[8] among patients with atrial fibrillation undergoing catheter ablation.

In our study, we showed that MHR, hs-CRP and β index were increased, and AoD was reduced in hypertensive patients. The significant linear correlation of hs-CRP with MHR confirmed the knowledge of the inflammatory biomarker for MHR. Additionally, we presented a significantly positive correlation between MHR and β index, and a negative correlation between MHR and AoD. To the best of our knowledge, the association of MHR with aortic elastic properties has not been previously studied. For the first time, we confirmed the association of hs-CRP as a previously recognized pro-inflammatory marker with MHR. Also, impaired aortic elastic properties in the hypertensive group was attributed to the inflammation as presented by MHR and hs-CRP.

Increased MHR (which means an increase in the monocyte count and/or decrease in HDL-C count) may play a direct role in the disruption of elastic properties of the aorta. Cytokines released by leukocytes might have a role in this pathogenetic process. The role of chemokines and their receptors is not clear in the pathogenesis of hypertension and the formation of aortic stiffness. They have an effect on the activation and transmigration of monocytes into the vessel wall, endothelial dysfunction, vascular smooth muscle cell proliferation and increased severity of hypertensive complications like aortic stiffness, atherosclerosis and chronic kidney disease. The close relationship between MHR and aortic elastic properties supports this hypothesis. Besides, increased MHR and aortic stiffness could arise as a result of the same pathologic insult which temporarily eluded explanation. In other words, the same pathogenic factors could both increase the MHR and disrupt the elastic properties of aorta. To better resolve these hypotheses, further studies are necessary. However, we concluded that our study was important to show the close relationship between MHR and the elastic properties of the aorta. Reviewing the relationship between MHR and impaired aortic elastic properties, this parameter can be used as an indicator to identify patients who are at a higher risk in terms of inflammatory and atherosclerotic burden. In patients with higher MHR, more intensive and aggressive control of cardiovascular risk factors (especially hypertension) can be considered. This parameter may also be utilized for monitoring the inflammatory response and the treatment efficacy. In this high-risk population, more close follow-up visits can be arranged. Ultimately, to clarify this hypothesis, further investigation is necessary by means of multi-center, large-scale randomized studies.

The most important limitation of our study was the calculation of aortic stiffness indices by only using brachial BP values and echocardiographic data rather than using the gold standard pulse wave velocity technique. Blood samples were taken from patients only once at the time of admission. However, several measurements showing temporal trend might be more beneficial. Additionally, we could not study various proinflammatory cytokines or biomarkers other than hs-CRP. The correlation between MHR and aortic stiffness index and distensibility may not be strong, which can be caused by a relatively small study size. Therefore, to debunk the strength of this relationship, multicenter, large-scale, randomized and prospective studies are needed.

CONCLUSIONS

Our study findings suggested that the MHR in correlation with hs-CRP as a proinflammatory marker was significantly associated with impaired aortic elastic properties in patients with essential hypertension. The MHR as

a simple, available and cheap marker for inflammation and oxidative stress was found to be an independent predictor of AoD and β index. However, future research is likely inevitable to provide more supporting information regarding direct assessment of aortic stiffness and MHR in patients with essential hypertension.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

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REFERENCES

1. Laurent S, Boutouyrie P, Asmar R, et al. Aortic stiffness is an independent predictor of all-cause and cardiovascular mortality in hypertensive patients. *Hypertension* 2001;37:1236-41.
2. Arnett DK, Evans GW, Riley WA. Arterial stiffness: a new cardiovascular risk factor? *Am J Epidemiol* 1994;140:669-82.
3. Celik T, Yuksel UC, Demirkol S, et al. Relationship between increased systemic inflammation and impaired aortic elasticity in young patients with prehypertension. *Blood Press Monit* 2011; 16:55-61.
4. Chae CU, Lee RT, Rifai N, Ridker PM. Blood pressure and inflammation in apparently healthy men. *Hypertension* 2001;38:399-403.
5. Murphy AJ. High density lipoprotein: assembly, structure, cargo, and functions. *ISRN Physiology* 2013;2013:20.
6. van den Bogaard B, Holleboom AG, Duivenvoorden R, et al. Patients with low HDL-cholesterol caused by mutations in LCAT have increased arterial stiffness. *Atherosclerosis* 2012;225:481-5.
7. Kanbay M, Solak Y, Unal HU, et al. Monocyte count/HDL cholesterol ratio and cardiovascular events in patients with chronic kidney disease. *Int Urol Nephrol* 2014;46:1619-25
8. Canpolat U, Aytemir K, Yorgun H, et al. The role of preprocedural monocyte-to-high-density lipoprotein ratio in prediction of atrial fibrillation recurrence after cryoballoon-based catheter ablation. *Europace* 2015;17:1807-15.
9. Cetin EH, Cetin MS, Canpolat U, et al. Monocyte/HDL-cholesterol ratio predicts the definite stent thrombosis after primary percutaneous coronary intervention for ST-segment elevation myocardial infarction. *Biomark Med* 2015;9:967-77.
10. Kundi H, Gok M, Kiziltunc E, et al. Relation between monocyte to high-density lipoprotein cholesterol ratio with presence and severity of ssolated coronary artery ectasia. *Am J Cardiol* 2015; 116:1685-9.
11. Canpolat U, Cetin EH, Cetin S, et al. Association of monocyte-to-HDL cholesterol ratio with slow coronary flow is linked to systemic inflammation. *Clin Appl Thromb Hemost* 2016;22:476-82.
12. Chobanian AV, Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *JAMA* 2003;289:2560-72.
13. Quinones MA, Otto CM, Stoddard M, et al. Recommendations for quantification of Doppler echocardiography: a report from the Doppler Quantification Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2002;15:167-84.
14. Lang RM, Bierig M, Devereux RB, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. *J Am Soc Echocardiogr* 2005;18:1440-63.
15. Stratos C, Stefanadis C, Kallikazaros I, et al. Ascending aorta distensibility abnormalities in hypertensive patients and response to nifedipine administration. *Am J Med* 1992;93:505-12.
16. Ardic I, Kaya MG, Yarlioglues M, et al. Impaired aortic elastic properties in normotensive patients with psoriasis. *Blood Pressure* 2010;19:351-8.
17. Maarek B, Simon AC, Levenson J, et al. Heterogeneity of the atherosclerotic process in systemic hypertension poorly controlled by drug treatment. *Am J Cardiol* 1987;59:414-7.
18. Kao YT, Wang ST, Shih CM, et al. Arterial stiffness index and coronary artery plaques in patients with subclinical coronary atherosclerosis. *Acta Cardiol Sin* 2015;31:59-65.
19. Boutouyrie P, Bussy C, Lacolley P, et al. Association between local pulse pressure, mean blood pressure, and large-artery remodeling. *Circulation* 1999;100:1387-93.
20. Boutouyrie P, Tropeano AI, Asmar R, et al. Aortic stiffness is an independent predictor of primary coronary events in hypertensive patients: a longitudinal study. *Hypertension* 2002;39:10-5.
21. Blacher J, Guerin AP, Pannier B, et al. Impact of aortic stiffness on survival in end-stage renal disease. *Circulation* 1999;99:2434-9.
22. Blankenhorn DH, Kramsch DM. Reversal of atherosis and sclerosis. The two components of atherosclerosis. *Circulation* 1989; 79:1-7.
23. Ridker PM, Rifai N, Rose L, et al. Comparison of C-reactive protein and low-density lipoprotein cholesterol levels in the prediction of first cardiovascular events. *N Engl J Med* 2002;347:1557-65.

24. Mahmud A, Feely J. Arterial stiffness is related to systemic inflammation in essential hypertension. *Hypertension* 2005;46: 1118-22.
25. Knorr M, Munzel T, Wenzel P. Interplay of NK cells and monocytes in vascular inflammation and myocardial infarction. *Front Physiol* 2014;5:295.
26. Mauno V, Hannu K, Esko K. Proinflammation and hypertension: a population-based study. *Mediators Inflamm* 2008;2008:619704.
27. Rehman A, Ismail SB, Naing L, et al. Reduction in arterial stiffness with angiotensin II antagonism and converting enzyme inhibition. A comparative study among malay hypertensive subjects with a known genetic profile. *Am J Hypertens* 2007;20:184-9.
28. Martynowicz H, Janus A, Nowacki D, et al. The role of chemokines in hypertension. *Adv Clin Exp Med* 2014;23:319-25.
29. Chapman CM, Beilby JP, McQuillan BM, et al. Monocyte count, but not C-reactive protein or interleukin-6, is an independent risk marker for subclinical carotid atherosclerosis. *Stroke* 2004; 35:1619-24.
30. Nicholls SJ, Tuzcu EM, Sipahi I, et al. Statins, high-density lipoprotein cholesterol, and regression of coronary atherosclerosis. *JAMA* 2007;297:499-508.
31. Tani S, Matsumoto M, Anazawa T, et al. Development of a model for prediction of coronary atherosclerotic regression: evaluation of high-density lipoprotein cholesterol level and peripheral blood monocyte count. *Heart Vessels* 2012;27:143-50.