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【 ORIGINAL ARTICLE 】

Association of Common Carotid Artery Measurements with N-terminal Pro B-type Natriuretic Peptide in Elderly Participants

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Abstract:
Objective Numerous studies have reported an association between common carotid artery (CCA) parameters and atherosclerotic cardiovascular disease (CVD). However, the association between CCA parameters and hemodynamic stress on the left ventricle in elderly patients remains unclear.
Methods We assessed CCA parameters, including the height-adjusted CCA interadventitial diameter (diameter/height), mean intima-media thickness (IMT), number of plaques, plaque score, resistance index (RI), and pulsatility index (PI) with ultrasonography, using serum N-terminal pro-brain natriuretic peptide (NT-proBNP) levels as a marker for hemodynamic stress on the left ventricle in 1,315 participants ≥70 years old without CVD. Of these participants, 706 had hypertension, defined as taking antihypertensive medications, having a systolic blood pressure ≥140 mmHg, and/or having a diastolic blood pressure ≥90 mmHg.
Results After adjusting for the confounding factors, the CCA interadventitial diameter/height was significantly associated with the log NT-proBNP in both the normotensive group (β=0.125, p=0.002) and hypertensive group (β=0.080, p=0.029). The RI was significantly associated with the log NT-proBNP in the hypertensive group (β=0.176, p<0.001) but not in the normotensive group. In addition, the PI was significantly associated with the log NT-proBNP in the hypertensive group (β=0.156, p<0.001) but not in the normotensive group. However, no significant association was observed between the mean IMT, number of plaques, and plaque score and log NT-proBNP.
Conclusion CCA measurements may be useful markers for hemodynamic stress on the left ventricle in elderly patients.

Key words: brain natriuretic peptide, carotid artery, elderly, resistance index, pulsatility index

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Introduction

Interaction between the systemic arterial tree and heart has been suggested to play an important role in the development of atherosclerotic cardiovascular disease (CVD) and heart failure (1, 2). The common carotid artery (CCA) is part of the elastic arterial tree that is believed to reflect aortic hemodynamics (3). Numerous studies have reported that morphologic parameters of the CCA are associated with atherosclerotic CVD (4-7). However, available data regarding the hemodynamic link between the CCA morphology and heart are limited (8, 9). Furthermore, the association of CCA flow parameters, including the resistance index (RI) and pulsatility index (PI) (10), with hemodynamic stress on the left ventricle has not been studied. Because the RI and PI of the CCA reflect vascular resistance of small blood vessels in cerebral arterial trees distal to the measurement

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point in the CCA (11), these parameters represent, at least in part, vascular resistance of the systemic vascular trees and the cardiac afterload.

N-terminal pro-brain natriuretic peptide (NT-proBNP), an established marker for heart failure (12), is released from the myocardium in response to increased cardiac wall stress due to volume and pressure overload (13, 14) and thus reflects hemodynamic stress on the left ventricle in individuals without cardiac disease (15, 16).

In the present study, we investigated whether or not CCA parameters, including interadventitial diameter, intima-media thickness (IMT), plaque number, plaque score, RI, and PI, were associated with the serum NT-proBNP levels in elderly participants without CVD, considering the differences between normotensive and hypertensive subjects.

Materials and Methods

Study participants

To investigate the CCA parameters and serum NT-proBNP levels, we recruited a total of 1,484 participants ≥70 years old following general health examinations from January 2015 to September 2017 at the Health Management and Promotion Center of the Hiroshima Atomic Bomb Casualty Council, Hiroshima, Japan. Data were collected regarding the participants' regular medications and medical histories (e.g. treatment for hypertension, diabetes mellitus, dyslipidemia, and CVDs) as well as drinking and smoking habits.

Among these participants, 16 were excluded because they did not complete the CA ultrasonographic measurements, 15 because of the presence of atrial fibrillation, 18 because of renal dysfunction (defined as serum creatinine ≥1.5 mg/dL), and 120 because they were being treated for or had a history of CVD (including coronary heart disease and stroke). In total, 1,315 participants [666 men and 649 women; mean age ± standard deviation (SD), 74.1±3.1 years; and mean body mass index (BMI) ± SD, 22.9±3.1 kg/m^2] were included in our study. Of these, 706 participants (54%) had hypertension [defined as taking antihypertensive medications (n=491), having a systolic BP (SBP) ≥140 mmHg, and/or having a diastolic BP (DBP) ≥90 mmHg] (17); 232 (18%) had diabetes mellitus (defined as taking antidiabetic medications and/or having HbA1c ≥6.5); 846 (64%) had dyslipidemia (defined as taking antihyperlipidemic medications and/or having low density lipoprotein (LDL)-C ≥140 mg/dL, high density lipoprotein (HDL)-C <40 mg/dL, and/or triglyceride ≥150 mg/dL); 90 (7%) were current smokers (defined as having a current smoking habit, regardless of the number of cigarettes smoked per day); and 422 (32%) were habitual drinkers (defined as drinking alcohol for ≥5 days/week, regardless of the amount consumed).

Informed consent was obtained from all participants. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Hiroshima Atomic Bomb Casualty Council committee.

CA ultrasonographic measurements

CA ultrasonography was performed by a blinded, experienced echographer using standard techniques with a HITACHI HIVISON Preirus (Hitachi Medical, Tokyo, Japan) equipped with a 7.5-MHz linear-array transducer. The participants were examined in the supine position with their head turned 45° from the site being scanned. The CCA interadventitial diameter was measured during the late phase of vascular contraction (end-diastolic phase) on the longitudinal scan at a point 10 mm proximal from the beginning of the carotid bulb. The CCA interadventitial diameter was defined as the distance between the adventitia-media interface on the near wall and the media-adventitia interface on the far wall. We calculated the height-adjusted index for the CCA interadventitial diameter as the CCA interadventitial diameter/height (mm/m) (9). The IMT was defined as the distance between the lumen-intima and media-adventitia interfaces. The greatest IMT was detected by scanning the CCA in the longitudinal axis view, and 2 measurements of IMT were performed at 10 mm proximal and 10 mm distal to the site of the greatest IMT. The mean IMT was then calculated as the mean of the IMT values at these three points (18).

Localized elevated lesions with a maximum thickness of >1 mm and a point of inflection on the surface of the intima-media complex were defined as plaques. Blood flow parameters, including the peak systolic velocity (PSV), end-diastolic velocity (EDV), and mean blood flow velocity (V mean), were measured with the sample volume located at the center of the CCA. An insonation angle ≤60° was maintained for all Doppler measurements, and RI was automatically calculated as (PSV-EDV)/PSV. Furthermore, the PI was automatically calculated as (PSV - EDV) / V_{mean}. In the subsequent analyses of this study, we used the measurements of the left CCA as the height-adjusted CCA diameter, mean IMT, RI, and PI. The number of plaques was counted in the left CCA and left internal CA. We calculated the plaque score by totaling the maximum thickness of all plaques in the same area (19).

We estimated the reliability of the ultrasonographic measurements from 134 pairs of scans performed up to a year apart, and the estimated correlation between the scans was 0.850 for the CCA interadventitial diameter, 0.854 for the mean IMT, 0.836 for the number of plaques, 0.948 for the plaque score, 0.698 for the RI, and 0.691 for the PI.

Blood sample and blood pressure measurements

We collected blood samples from all participants for measuring hemoglobin concentration and serum levels of creatinine and NT-proBNP. NT-proBNP was measured by a chemiluminescent enzyme immunoassay using a Cobas e601 analyzer (Roche Diagnostics, Tokyo, Japan) (20). A high NT-proBNP level was defined as NT-proBNP ≥ 125 pg/mL (21). Using a digital, automatic blood pressure (BP)-measuring instrument (Terumo, Tokyo, Japan or Omron

Table 1. Clinical Characteristics of Participants.

		All	Normotensive	Hypertensive	p
N		1,315	609	706	
Mean age	(years)	74.1±3.1	73.8±2.8	74.3±3.3	0.012
Female	[n (%)]	649 (49)	327 (54)	322 (46)	0.003
BMI	(kg/m^2)	22.9±3.1	22.1±2.7	23.7±3.2	<0.001
Hemoglobin	(g/dL)	13.8±1.3	13.7±1.2	13.9±1.3	<0.001
Creatinine	(mg/dL)	0.77±0.18	0.75±0.16	0.79±0.19	<0.001
SBP	(mmHg)	132±17	122±11	139±16	<0.001
DBP	(mmHg)	75±11	71±9	79±12	<0.001
PP	(mmHg)	56±13	51±10	61±14	<0.001
HbA1c	(%)	6.1±0.6	6.0±0.6	6.1±0.7	0.068
LDL-C	(mg/dL)	122±29	125±28	120±29	<0.001
HDL-C	(mg/dL)	65±17	67±17	63±16	<0.001
TG	(mg/dL)	129±93	121±70	136±109	<0.001
Current smoker	[n (%)]	90 (7)	39 (6)	51 (7)	0.557
Habitual drinker	[n (%)]	422 (32)	167 (27)	255 (36)	<0.001
Diabetes	[n (%)]	232 (18)	96 (16)	136 (19)	0.096
Dyslipidemia	[n (%)]	846 (64)	387 (64)	459 (65)	0.580
NT-proBNP[a]	(pg/mL)	69 (42–113)	68 (41–103)	71.5 (43–119)	0.035
Log NT-proBNP[a]		4.23 (3.74–4.73)	4.18 (3.71–4.63)	4.28 (3.76–4.78)	0.035
Ultrasonographic measurements of the common carotid artery					
Diameter	(mm)	7.4±0.8	7.1±0.8	7.6±0.8	<0.001
Diameter/height	(mm/m)	4.68±0.51	4.52±0.47	4.82±0.50	<0.001
Mean IMT	(mm)	0.9±0.2	0.8±0.2	0.9±0.2	<0.001
Number of plaques	(n)	1.9±1.2	1.8±1.2	2.1±1.3	<0.001
Plaque score		2.8±2.1	2.5±1.9	3.1±2.2	<0.001
RI		0.74±0.06	0.73±0.05	0.75±0.05	<0.001
PI		1.64±0.35	1.57±0.32	1.71±0.36	<0.001

Data are expressed as mean±standard deviation or as number and percentage.
[a]Data are provided as the median values (interquartile range, 25–75%).
BMI: body mass index, DBP: diastolic blood pressure, IMT: intima-media thickness, NT-proBNP: N-terminal pro-brain natriuretic peptide, PI: pulsatility index, PP: pulse pressure, RI: resistance index, SBP: systolic blood pressure

Healthcare, Kyoto, Japan), BP was measured with the patient in a seated position on a chair with back and arm support at the heart level after resting for >5 minutes when the participants underwent health examinations.

Statistical analyses

Continuous variables are expressed as the mean ± standard deviation or median (interquartile range, 25-75%). The differences between the normotensive and hypertensive groups were compared using Wilcoxon's rank-sum test. Categorical variables were summarized as percentages and analyzed using the chi-squared test. Because the serum NT-proBNP level showed a skewed distribution, logarithmic transformation was carried out before the subsequent analyses. The relationships between individual CCA parameters and the log NT-proBNP were evaluated using Spearman's rank correlation. To adjust for the confounding factors that were correlated significantly with the log NT-proBNP, as determined by Spearman's rank correlation, the following two multivariable regression models were used: model 1 included the age, sex, BMI, hemoglobin concentration, SBP, DBP, and the presence of diabetes and dyslipidemia; model 2 included the pulse pressure (PP) instead of SBP and DBP in model 1. Consequently, we stratified the participants into subgroups based on sex to investigate the association between individual CCA parameters and log NT-proBNP using models 1 and 2.

We considered $p<0.05$ as statistically significant. All statistical analyses were performed using the JMP 10 statistical software program (SAS Institute, Cary, USA).

Results

Participants' characteristics and parameters of ultrasonographic measurements of the CCA are summarized in Table 1. The median (interquartile range, 25-75%) NT-proBNP level was 68 pg/mL (range, 41-103 pg/mL) and 71.5 pg/mL (range, 43-119 pg/mL) in the normotensive and hypertensive groups, respectively. All CCA parameters, including the CCA interadventitial diameter/height, mean IMT, number of plaques, plaque score, RI, and PI, were significantly higher in the hypertensive group than in the normotensive group.

Fig. 1 shows the association of individual CCA parame-

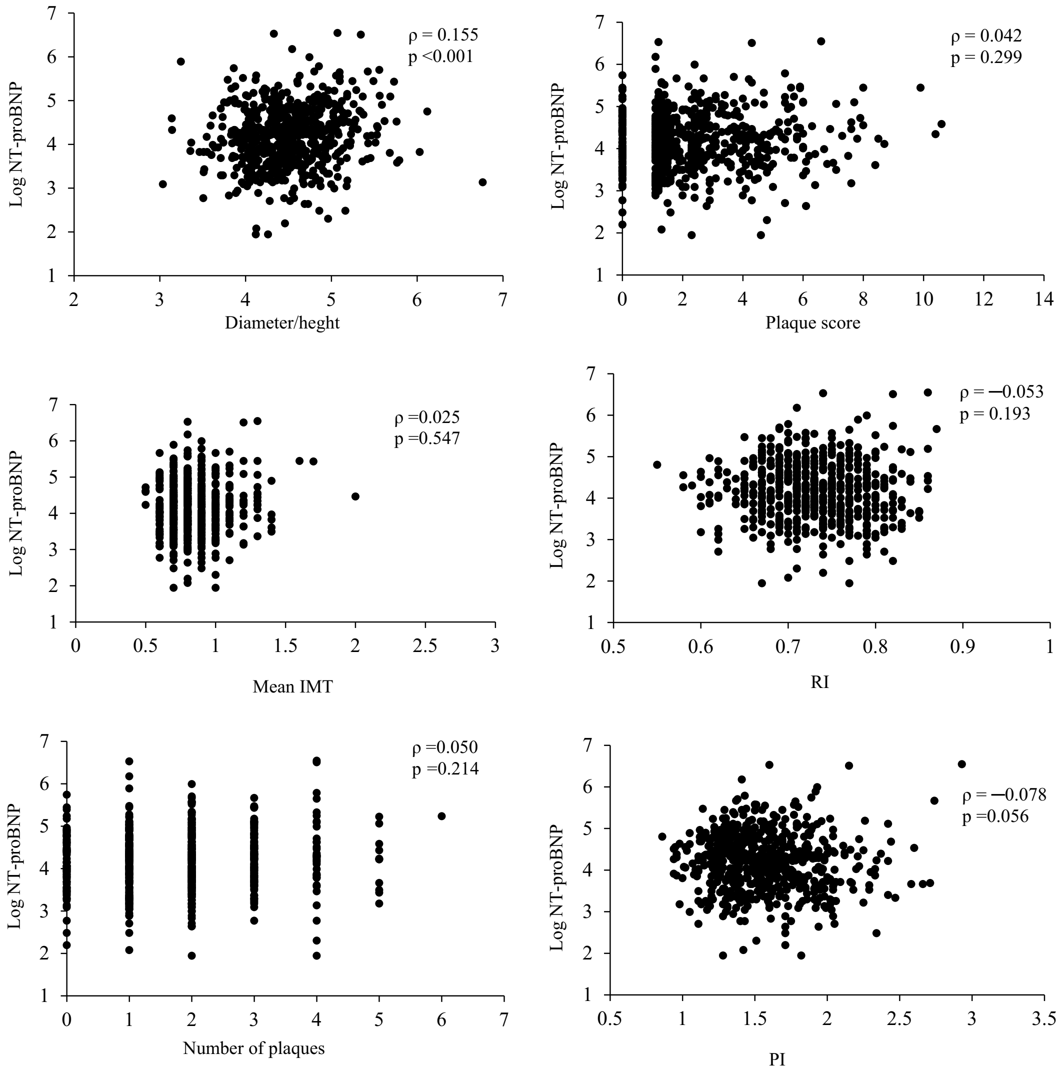

Figure 1. The association of individual CCA parameters with the log NT-proBNP in the normotensive group. IMT: intima-media thickness, NT-proBNP: N-terminal pro-brain natriuretic peptide, PI: pulsatility index, RI: resistance index, ρ: Spearman's rank correlation coefficient

ters with the log NT-proBNP in the normotensive group. The CCA interadventitial diameter/height was significantly associated with the log NT-proBNP (ρ=0.155, p<0.001). However, the mean IMT (ρ=0.025, p=0.547), number of plaques (ρ=0.050, p=0.214), plaque score (ρ=0.042, p=0.299), RI (ρ=–0.053, p=0.193), and PI (ρ=–0.078, p=0.056) were not significantly associated with the log NT-proBNP. Fig. 2 shows the association of individual CCA parameters with the log NT-proBNP in the hypertensive group. The CCA interadventitial diameter/height was significantly associated with the log NT-proBNP (ρ=0.132, p<0.001). In addition, both the RI (ρ=0.154, p<0.001) and PI (ρ=0.092, p=0.014) were significantly associated with the log NT-proBNP. However, the mean IMT (ρ=0.062, p=0.099), number of plaques (ρ=–0.010, p=0.801), and plaque score (ρ=0.003, p=0.938) were not significantly associated with the log NT-proBNP.

Table 2 shows the Spearman's rank correlations between the clinical characteristics and log NT-proBNP. The age, gender, SBP, and PP were positively associated with the log NT-proBNP, whereas the BMI, hemoglobin concentration, DBP, and presence of diabetes and dyslipidemia were negatively associated with the log NT-proBNP.

Table 3 shows the results of the multiple linear regression analysis. After adjusting for the confounding factors, including SBP and DBP (model 1), the CCA interadventitial diameter/height was significantly associated with the log NT-proBNP in both the normotensive group (β=0.125, p=0.002) and hypertensive group (β=0.080, p=0.029). In addition, both the RI and PI were significantly associated with the log NT-proBNP in the hypertensive group (β=0.176, p<0.001 and β=0.156, p<0.001, respectively) but not in the normotensive group. Similar results were obtained in model 2, which included PP.

Table 4 shows the results of the sex-stratified analysis. In the hypertensive group, the CCA interadventitial diameter/height was significantly associated with the log NT-proBNP in men but not in women. Conversely, the RI and PI were significantly associated with the log NT-proBNP in both men and women.

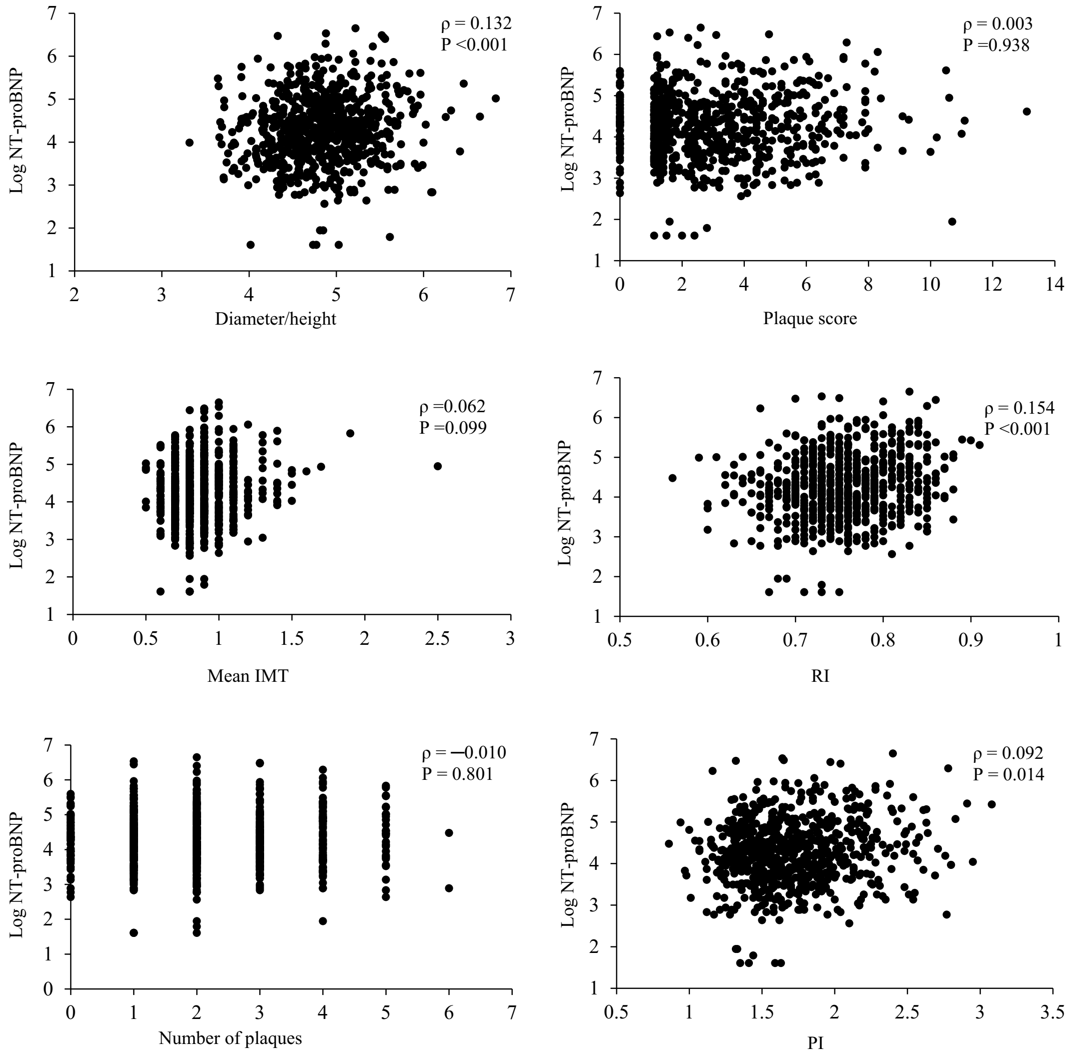

Figure 2. **The association of individual CCA parameters with the log NT-proBNP in the hypertensive group. IMT: intima-media thickness, NT-proBNP: N-terminal pro-brain natriuretic peptide, PI: pulsatility index, RI: resistance index, ρ: Spearman's rank correlation coefficient**

Table 2. **Spearman's Rank Correlation between Clinical Characteristics of Participants and Log NT-proBNP.**

Variables	Log NT-proBNP	
	ρ	p
Age, year	0.145	<0.001
Female	0.137	<0.001
BMI, kg/m^2	-0.170	<0.001
Hemoglobin, g/dL	-0.251	<0.001
Creatinine, mg/dL	-0.012	0.676
SBP, mmHg	0.092	<0.001
DBP, mmHg	-0.058	0.036
PP, mmHg	0.178	<0.001
Current smoker, yes or no	0.020	0.461
Habitual drinker, yes or no	0.009	0.743
Anti-hypertensive medication, yes or no	-0.013	0.643
Diabetes, yes or no	-0.091	0.001
Dyslipidemia, yes or no	-0.086	0.002

BMI: body mass index, DBP: diastolic blood pressure, NT-proBNP: N-terminal pro-brain natriuretic peptide, PP: pulse pressure, SBP: systolic blood pressure

Discussion

In this study, the mean IMT, number of plaques, and plaque score in the CCA were not associated with the serum NT-proBNP levels in the elderly participants without CVD, suggesting that the local development of atherosclerosis in the CCA has no hemodynamic impact on the left ventricle. Conversely, the height-adjusted CCA interadventitial diameter was positively associated with the serum NT-proBNP level, suggesting that there is a significant hemodynamic linkage between CCA remodeling and the left ventricle in elderly participants with and without hypertension. Furthermore, the RI and PI of the CCA, which are markers for vascular resistance distal to the measurement point (10, 11), were positively associated with the serum NT-proBNP level in the elderly hypertensive participants but not in the elderly normotensive participants, suggesting that these flow parameters may be useful markers for hemodynamic stress on the left ventricle in elderly hypertensive individuals.

Table 3. Multiple Linear Regression Analysis for Log NT-proBNP in Normotensive and Hypertensive

Variables	β	p	β	p	β	p
Normotensive (n=609)						
Model 1						
Age, year	0.076	0.057	0.104	0.008	0.104	0.008
Female	0.044	0.363	0.031	0.536	0.028	0.578
BMI, kg/m^2	-0.114	0.006	-0.088	0.033	-0.089	0.032
Hemoglobin, g/dL	-0.250	<0.001	-0.263	<0.001	-0.264	<0.001
Diabetes, yes or no	0.115	0.003	0.222	0.005	0.111	0.004
Dyslipidemia, yes or no	0.014	0.721	0.013	0.749	0.012	0.758
SBP, mmHg	0.090	0.058	0.102	0.043	0.100	0.043
DBP, mmHg	-0.082	0.083	-0.082	0.106	-0.081	0.106
Diameter/height, mm/m	0.125	0.002				
RI			0.015	0.738		
PI					0.022	0.621
Model 2						
Age, year	0.076	0.057	0.104	0.008	0.104	0.008
Female	0.044	0.363	0.031	0.536	0.028	0.578
BMI, kg/m^2	-0.115	0.006	-0.088	0.032	-0.089	0.030
Hemoglobin, g/dL	-0.252	<0.001	-0.263	<0.001	-0.264	<0.001
Diabetes, yes or no	0.114	0.003	0.111	0.005	0.111	0.004
Dyslipidemia, yes or no	0.014	0.728	0.012	0.750	0.012	0.759
PP, mmHg	0.080	0.040	0.088	0.038	0.087	0.037
Diameter/height, mm/m	0.124	0.002				
RI			0.015	0.733		
PI					0.022	0.618
Hypertensive (n=706)						
Model 1						
Age, year	0.128	<0.001	0.128	<0.001	0.133	<0.001
Female	0.023	0.583	-0.022	0.613	-0.024	0.586
BMI, kg/m^2	-0.141	<0.001	-0.139	<0.001	-0.140	<0.001
Hemoglobin, g/dL	-0.267	<0.001	-0.195	<0.001	-0.200	<0.001
Diabetes, yes or no	0.070	0.048	0.078	0.027	0.076	0.031
Dyslipidemia, yes or no	0.070	0.054	0.072	0.047	0.069	0.058
SBP, mmHg	0.206	<0.001	0.150	<0.001	0.168	<0.001
DBP, mmHg	-0.126	0.005	-0.051	0.287	-0.070	0.136
Diameter/height, mm/m	0.080	0.029				
RI			0.176	<0.001		
PI					0.156	<0.001
Model 2						
Age, year	0.127	<0.001	0.126	<0.001	0.131	<0.001
Female	0.023	0.588	-0.020	0.643	-0.022	0.615
BMI, kg/m^2	-0.141	<0.001	-0.136	<0.001	-0.138	<0.001
Hemoglobin, g/dL	-0.161	<0.001	-0.176	<0.001	-0.183	<0.001
Diabetes, yes or no	0.072	0.044	0.081	0.021	0.079	0.025
Dyslipidemia, yes or no	0.070	0.054	0.072	0.047	0.069	0.057
PP, mmHg	0.173	<0.001	0.124	0.001	0.139	<0.001
Diameter/height, mm/m	0.080	0.028				
RI			0.165	<0.001		
PI					0.147	<0.001

BMI: body mass index, DBP: diastolic blood pressure, NT-proBNP: N-terminal pro-brain natriuretic peptide, PI: pulsatility index, PP: pulse pressure, RI: resistance index. SBP: systolic blood pressure, β: standardized partial regression coefficient

Table 4. Sex-stratified Analysis in Multiple Linear Regression for Log NT-proBNP.

	Model 1		Model 2	
	β	p	β	p
Normotensive				
Male (n=282)				
Diameter/height, mm/m	0.121	0.035	0.122	0.035
RI	0.017	0.765	0.016	0.177
PI	0.035	0.540	0.033	0.561
Female (n=327)				
Diameter/height, mm/m	0.125	0.034	0.121	0.037
RI	0.034	0.583	0.036	0.559
PI	0.025	0.684	0.026	0.666
Hypertensive				
Male (n=384)				
Diameter/height, mm/m	0.108	0.029	0.108	0.029
RI	0.181	<0.001	0.175	<0.001
PI	0.149	0.003	0.144	0.004
Female (n=322)				
Diameter/height, mm/m	0.038	0.497	0.043	0.438
RI	0.146	0.014	0.128	0.027
PI	0.140	0.017	0.123	0.032

Model 1 included age, sex, body mass index, hemoglobin, SBP, DBP, and the presence of diabetes and dyslipidemia. Model 2 included pulse pressure instead of SBP and DBP in model 1.
DBP: diastolic blood pressure, NT-proBNP: N-terminal pro-brain natriuretic peptide, PI: pulsatility index, RI: resistance index, SBP: systolic blood pressure

Although numerous studies have reported that CCA morphologic parameters, such as the IMT and interadventitial diameter, are associated with atherosclerotic CVD (4-7), little is known about the hemodynamic linkage between CCA morphology and the heart. Recently, a few studies have reported that the CCA luminal diameter is associated with the serum NT-proBNP levels and the prevalence of left ventricular hypertrophy in middle-aged individuals (8, 9). Scuteri et al. reported that the central SBP was significantly higher in patients with observed wall thickening and lumen dilatation in the CCA than in those without wall thickening or lumen dilatation in the CCA (22), suggesting a hemodynamic linkage between CCA remodeling and the left ventricle. Consistent with these findings, the present study showed that the height-adjusted CCA interadventitial diameter was positively associated with the serum NT-proBNP level in elderly participants. Conversely, the mean IMT, number of plaques, and plaque score were not associated with the serum NT-proBNP levels in this study. NT-proBNP exerts compensatory effects for the increased afterload through the induction of vasodilation, increasing sodium excretion, and inhibition of the sympathetic nervous system and renin-angiotensin-aldosterone system (23). In addition, NT-proBNP is involved in the adipose tissue function, such as via the modulation of the release of adipokines (24, 25), and the serum NT-proBNP level is inversely associated with the total cholesterol and low-density lipoprotein cholesterol levels (26). These compensatory effects of NT-proBNP may have attenuated the development of arteriosclerosis and plaque formation, thereby reducing the association of the number of plaques as well as the plaque score with the serum NT-proBNP level for arterial stiffness.

The RI is simply calculated using two-point flow parameters (PSV and EDV) and has been reported to be a marker for stroke prevalence (27). The PI, the which is calculated based on the mean blood flow velocity during the cardiac cycle, is more frequently used for assessing the cerebral hemodynamic status and risk of stroke than RI (28, 29). Lee et al. reported that the RI and PI of the CCA correlated with Framingham risk scores in patients with hypertension, suggesting that these CCA flow parameters reflect future coronary heart disease risk (30). However, no studies have investigated the association between these CCA flow parameters and hemodynamic stress on the left ventricle. In this study, we demonstrated that the RI and PI of the CCA were positively associated with the serum NT-proBNP level in elderly hypertensive participants but not in normotensive participants. These findings indicate that the presence of hypertension is a key element involved in the hemodynamic linkage between the heart and vascular resistance of small blood vessels in cerebral arterial trees.

In the present study, we assessed the association between CCA parameters and the serum NT-proBNP level by adjusting for confounding factors, including the age, sex (31), BMI (32), hemoglobin concentration (33), and indices of blood pressure (34). The sex-related differences in the serum NT-proBNP level are well known (31), and consistent with previous reports, we confirmed the significantly higher serum NT-proBNP level in women than in men in this study (data not shown). However, the sex-stratified analysis revealed that these sex-related differences did not affect the association between the CCA parameters and the serum NT-proBNP level, except for the height-adjusted CCA interadventitial diameter in hypertensive women. We were unable to evaluate any age-related differences because only elderly patients ≥70 years of age were included in the study. The vascular resistance of small blood vessels and the pulsatile load in the elastic arterial tree increase with age and can significantly contribute to the hemodynamic linkage between CCA remodeling and the left ventricle stress. A previous study reported that hypertension significantly influenced both the vessel diameter and wall thickness in participants who were >50 years of age. Such a relationship was not observed in younger participants (35). The association between CCA parameters and the NT-proBNP level may thus become significant in elderly individuals.

At present, approximately 50% of all heart failure patients are considered to have heart failure with a preserved ejection fraction (HFpEF), and its prevalence continues to increase with the growth of the elderly population (36). Although the pathophysiology of HFpEF is partially understood, the interaction between the systemic arterial tree and heart may play an important role in the underlying mechanisms (37). Liao et al. reported the gradual enlargement of the CCA lumen diameter from a healthy to a hypertensive status and finally to HFpEF, suggesting that the CCA lumen diameter is useful for identifying HFpEF patients (38). Overall, our results suggest that CCA flow parameters and diameter have a significant hemodynamic linkage with the heart in elderly hypertensive participants at risk of HFpEF (36). In clinical practice, these CCA measurements may be useful markers for detecting an increased risk of heart failure in elderly patients, given that these CCA parameters are easily assessed by ultrasonography.

Several limitations associated with the present study warrant mention. First, because of its cross-sectional study design, a causal relationship between CCA measurements and NT-proBNP may not be inferred. Second, the types of antihypertensive agents used were not assessed in participants being treated for hypertension, although the effects on the cardiac function may differ among antihypertensive agents. Finally, we excluded participants with cardiac disease; however, we were unable to rule out the possibility that our study population may have included participants with subclinical cardiac disease, as we did not assess the cardiac geometry or function using objective methods. In particular, subclinical aortic regurgitation can increase the RI, PI, and left ventricular volume overload, leading to increased serum NT-proBNP level.

In conclusion, our study showed that the height-adjusted CCA interadventitial diameter was positively associated with the serum NT-proBNP level in elderly participants with and without hypertension. The RI and PI of the CCA were also positively associated with the serum NT-proBNP levels in hypertensive patients. These parameters may shed light on the effects of hemodynamic stress on the left ventricle in elderly people.

The authors state that they have no Conflict of Interest (COI).

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