Original Article

Determinants of Functional and Structural Properties of Large Arteries in Healthy Individuals

Elaine Cristina Tolezani, Valéria Costa-Hong, Gustavo Correia, Alfredo José Mansur, Luciano Ferreira Drager, Luiz Aparecido Bortolotto

Instituto do Coração, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, São Paulo, SP – Brazil

Abstract

Background: **Changes in the properties of large arteries correlate with higher cardiovascular risk. Recent guidelines have included the assessment of those properties to detect subclinical disease. Establishing reference values for the assessment methods as well as determinants of the arterial parameters and their correlations in healthy individuals is important to stratify patients.**

Objective: **To assess, in healthy adults, the distribution of the values of pulse wave velocity, diameter, intima-media thickness and relative distensibility of the carotid artery, in addition to assessing the demographic and clinical determinants of those parameters and their correlations.**

Methods: **This study evaluated 210 individuals (54% women; mean age, 44 ± 13 years) with no evidence of cardiovascular disease. The carotid-femoral pulse wave velocity was measured with a Complior® device. The functional and structural properties of the carotid artery were assessed by using radiofrequency ultrasound.**

Results: **The means of the following parameters were: pulse wave velocity, 8.7 ± 1.5 m/s; diameter, 6,707.9 ± 861.6 μm; intima-media thickness, 601 ± 131 μm; relative distensibility, 5.3 ± 2.1%. No significant difference related to sex or ethnicity was observed. On multiple linear logistic regression, the factors independently related to the vascular parameters were: pulse wave velocity, to age ($p < 0.01$) and triglycerides ($p = 0.02$); intima-media thickness, to age ($p < 0.01$); diameter, to creatinine ($p = 0.03$) and age ($p = 0.02$); relative distensibility, to age ($p < 0.01$) and systolic and diastolic blood pressures ($p = 0.02$ and $p = 0.01$, respectively). Pulse wave velocity showed a positive correlation with intima-media thickness ($p < 0.01$) and with relative distensibility ($p < 0.01$), while diameter showed a positive correlation with distensibility ($p = 0.03$).**

Conclusion: **In healthy individuals, age was the major factor related to aortic stiffness, while age and diastolic blood pressure related to the carotid functional measure. The carotid artery structure was directly related to aortic stiffness, which was inversely related to the carotid artery functional property. (Arq Bras Cardiol. 2014; 103(5):426-432)**

Keywords: **Arteries; Arterial Pressure; Vascular Stiffness; Pulse Wave Analysis; Carotid Intima-Media Thickness.**

Introduction

The importance of arterial stiffness to the development of cardiovascular diseases has been emphasized in past years. Changes in the functional and structural properties of large arteries have been correlated with greater cardiovascular risk in different populations[1-4], and, although considered to be intrinsic to the vascular aging process[3,5,6], they are influenced by other diseases and risk factors[7,8], such as sex, dyslipidemia, diabetes, increased heart rate (HR), smoking[9], arterial hypertension, chronic renal disease and obesity[10-12].

New and accessible methods enable the non-invasive assessment of functional and structural properties of large arteries. The European guidelines of arterial hypertension[13] and the VI Brazilian Guidelines on Hypertension[14] include measurements of aortic stiffness and carotid artery intima-media thickness (IMT) as methods to assess the possible subclinical cardiovascular disease of hypertensive patients.

Aortic stiffness and carotid artery IMT are important parameters for cardiovascular risk assessment, being currently used for the detection of subclinical disease, minimizing poorer prognoses. To assess arterial stiffness, pulse wave velocity (PWV) measurement is gold-standard, because of the method reproducibility and reliability, in addition to its association with cardiovascular risk in different populations, independently of the risk factors related[15,16].

To establish a reference pattern for the functional and structural assessment methods of arterial properties is required so that the measurement of arterial stiffness and other arterial properties can express the presence of subclinical cardiovascular disease. In addition, the major

Mailing Address: Valéria Costa-Hong •
Avenida Dr. Eneias de Carvalho Aguiar, Cerqueira Cesar. Postal Code 05403-000, São Paulo, SP – Brazil
E-mail: hong.valeria@gmail.com
Manuscript received October 23, 2013; revised manuscript February 26, 2014; accepted May 05, 2014.

DOI: 10.5935/abc.20140124

clinical and demographic determinants of the parameters obtained with those methods and their correlations need to be established.

In Brazil, a reference pattern for those methods and for assessing the major determinants of the function and structure of large arteries is yet to be studied, that being the purpose of this study.

This study aimed at assessing the following in healthy adults: (1) the distribution of aortic PWV values, as well as the diameter, IMT and relative distensibility of the carotid artery, to define the reference values for the methods applied; (2) the major demographic and clinical determinants of the parameters obtained by using those methods; and (3) the correlations between the arterial parameters obtained by using the different methods.

Methods

This study included 210 asymptomatic adults of both sexes (age range, 18 to 80 years), with no evidence of current cardiovascular disease after clinical and laboratory assessment, and not using any medication. They had participated as control groups in research projects duly approved by the Ethics Committee of the São Paulo University Medical School (Table 1).

For sample calculation, a minimum number of 30 patients per age group was considered, based on the power to detect changes in PWV measurements, according to the reproducibility and sensitivity of the test observed at our service. The method had intraobserver and interobserver reproducibility coefficients of 0.935 and 0.890, respectively. That minimum number per age group was calculated by using the JMP statistical software. Thus, subdividing the population into seven age groups, from 18 to 80 years, 210 individuals were obtained. However, because of the difficulty of getting individuals older than 70 years with no comorbidity, the same number of individuals initially calculated was maintained, distributed according to a population curve, predominating ages between 41 and 50 years.

Written informed consents were provided in the respective projects. The Chest-BR project, assessing individuals with no clinical cardiovascular disease, involved 143 patients. All underwent complete clinical assessment, laboratory tests, cardiopulmonary exercise test, and echocardiography, and no change in any of those assessments was evidenced.

The clinical assessment included careful anamnesis for data collection, such as age, sex, race and presence or lack of exclusion criteria. Ethnicity was recorded according to the individuals' self-reports and classified as white, black, mixed and yellow. To make the result presentation clearer, the population studied was divided into white and non-white. A Filizola scale, Personal model, was used to measure the weight and height of barefoot individuals wearing light clothes. The body mass index (BMI) was determined with the following formula: body weight (kg)/height^2 (m^2). Brachial systolic and diastolic blood pressures (SBP and DBP, respectively), as well as HR, were measured by using the automated Omron HEM 705-CP device, duly validated, according to the international protocol of the British Hypertension Society (BHS)[17] and the Association for Advancement of Medical Instrumentation (AAMI)[18]. The device was used on the right arm, with the individual sitting and after a 5-minute rest, according to the recommendations of the VI Brazilian Guidelines on Hypertension[14]. Pulse pressure (PP) was determined by using the formula: SBP – DBP.

Laboratory tests were performed at the laboratory of the institution after a 12-hour fasting period.

Individuals with any of the following clinical conditions were excluded from the study: chronic renal failure (creatinine > 1.4 mg/dL); hepatic failure; systemic arterial hypertension [blood pressure (BP) > 140/90 mmHg or patient on anti-hypertensive medication]; inflammatory diseases; neoplasias; endocrine disorders; hematologic diseases; peripheral vascular diseases; hypercholesterolemia (total cholesterol > 240 mg/dL or patient on lipid-lowering medication); cardiomyopathies; valvular heart diseases; congenital diseases; and obesity (BMI > 30).

Methods to assess the arterial parameters

The PWV is automatically measured by recording simultaneous pulse waves captured by external sensors on two known points of the arterial tree (carotid and femoral arteries), being calculated as the propagation distance between those two points divided by the time necessary to travel between them, provided by the software of the device. That measurement was obtained with the Complior® device (Gonesse, France), already validated and used in several studies at our laboratory[19-22]. The PWV was assessed on the carotid-femoral arterial segment, and represented the measure of the pulse wave propagation along the aorta. To obtain PWV of each patient, ten good-quality curves were selected, and the mean calculated. The curves were acquired with the individuals placed in the dorsal decubitus position.

Table 1 – Research projects used as data bank

Approval protocol number	Project's name
2431/04/51	Impact of Obstructive Sleep Apnea Syndrome on the Structural and Functional Properties of Large Arteries
721/04	Influence of the polymorphism of alpha2-1, alpha2-c and beta1 adrenergic receptor genes on the cardiovascular regulation of children of hypertensives
2403/04/23	Determinants of arterial stiffness and carotid intima-media thickness in familial hypercholesterolemia
852/03	Chest-BR

The functional and anatomical properties of the right carotid artery were assessed by using an ultrasound device consisting of a vessel wall echo-tracking system (Wall-Track System, Pie Medical, Maastricht, The Netherlands), that analyses the radiofrequency signals, and was developed to measure wall movements of superficial large arteries based on location by use of B-mode conventional vascular ultrasound. The method has been validated and used in clinical studies[23-26]. The accuracy of that system is 30 μm for measuring the diastolic diameter and lower than 1 μm for the pulsatile diameter variation (difference between the systolic and diastolic diameters). The right common carotid artery was assessed 2 cm bellow the carotid bifurcation, and the following measurements were taken: carotid artery IMT and diameter; beat-to-beat carotid systolic-diastolic variation; and percentage of that systolic-diastolic variation[7,23].

Statistical analysis

The Kolmogorov-Smirnov test was used to assess the distribution of continuous variables. The variables were expressed as mean ± standard deviation (SD), median [25 – 75 percentiles] or percentage, as appropriate.

The correlation coefficient (r) between clinical, anthropometric, biochemical data, PWV and carotid parameters was obtained by use of the Pearson method for normally distributed variables, and the Spearman method for nonparametric distributed variables.

Analysis of variance (ANOVA) was used to compare between variables of different groups, the differences being confirmed by using the Tukey-Kramer test.

Factors independently associated with functional and structural vascular changes were assessed by using different linear regression models (uni- and multivariate), considering the PWV and carotid arterial parameters (diameter, distensibility or IMT) as dependent variables. For multivariate analysis, the following variables were considered independent: age, sex, ethnicity, smoking, weight, height, BMI, SBP, DBP, PP, glycemia, total cholesterol, LDL-cholesterol, HDL-cholesterol, triglycerides and C-reactive protein. For each model, the estimated parameters, SD, descriptive significance level (p) and correlation coefficient (r) were presented.

The JMP statistical software, version 5.0, was used and p values < 0.05 were considered statistically significant.

Results

Table 2 shows the major clinical, laboratory and demographic characteristics of the participants.

Measurements of arterial properties

The following means were obtained: PWV, 8.7 ± 1.5 m/s; carotid artery diameter, 6,707.9 ± 861.6 μm; carotid IMT, 601±131 μm; and relative distensibility of the carotid artery, 5.3 ± 2.1%.

Correlation with demographic parameters

No significant difference in the vascular parameters was observed regarding sex and ethnicity.

Table 2 – Clinical, laboratory and demographic characteristics of the participants, n = 210

Variables	Sample (210)
Age, years	44 ± 13
Female sex, n (%)	109 (54)
White, n (%)	141 (76)
Body mass index, kg/m²	25 ± 3
Systolic blood pressure, mmHg	118 ± 13
Diastolic blood pressure, mmHg	75 ± 10
Creatinine, mg/dL	0.9 ± 0.2
Total cholesterol, mg/dL	191 ± 32
Triglycerides, mg/dL	100 ± 32
LDL-cholesterol, mg/dL	120 ± 28
HDL-cholesterol, mg/dL	39 ± 6
Hematocrit, %	42 ± 3
Glycemia, mg/dL	92 ± 7

Correlation with age

Age had a significant and positive correlation with PWV ($r = 0.50$; $p \leq 0.01$), diameter ($r = 0.18$; $p \leq 0.01$) and carotid artery IMT ($r = 0.28$; $p \leq 0.01$), and negative correlation with relative distensibility of the carotid artery ($r = -0.33$; $p \leq 0.01$).

Table 3 shows the distribution of PWV values, carotid artery diameter, IMT and relative distensibility according to different age group. A progressive increase in PWV, carotid artery diameter and IMT, in addition to a decrease in the relative distensibility of the carotid artery according to category were observed.

Correlation with anthropometric variables

The relative distensibility of the carotid artery had a significant and negative correlation with BMI ($r = -0.21$; $p = 0.03$), while the carotid artery diameter had a significant and positive correlation with BMI ($r = 0.22$; $p = 0.002$). The PWV showed no correlation with the anthropometric parameters in that population.

Correlation with blood pressure and heart rate

The PWV had a significant and positive correlation with SBP ($r = 0.24$; $p \leq 0.01$), DBP ($r = 0.26$; $p \leq 0.01$) and PP ($r = 0.17$; $p = 0.01$), while the carotid artery diameter had a significant and positive correlation with SBP ($r = 0.17$; $p = 0.01$) and DBP ($r = 0.2$; $p = 0.004$). The relative distensibility of the carotid artery had a significant and inverse correlation with SBP ($r = -0.19$; $p = 0.01$), DBP ($r = -0.32$; $p \leq 0.01$) and HR ($r = -0.18$; $p = 0.01$). The carotid artery IMT had a significant and positive correlation with SBP ($r = 0.15$; $p = 0.03$), PP ($r = 0.18$; $p = 0.01$) and HR ($r = 0.16$; $p = 0.03$).

The individuals were classified according to the VI Brazilian Guidelines on Hypertension[14] aiming at categorizing the values of aortic PWV, carotid artery IMT, diameter, and relative distensibility according to BP categories not yet considered as arterial hypertension (Table 4). By using ANOVA, both PWV and carotid artery diameter showed an increase per BP range, while carotid artery distensibility was smaller in the borderline BP range.

Correlation of vascular parameters with laboratory variables

The PWV correlated with cholesterol ($r = 0.21$; $p < 0.01$), triglycerides ($r = 0.26$; $p < 0.01$), LDL-cholesterol ($r = 0.15$; $p = 0.04$), HDL-cholesterol ($r = 0.14$; $p = 0.04$) and glycemia ($r = 0.19$; $p < 0.01$). The carotid artery diameter correlated with triglycerides ($r = 0.25$; $p < 0.01$), hematocrit ($r = 0.26$; $p < 0.01$), hemoglobin ($r = 0.26$; $p < 0.01$), glycemia ($r = 0.21$; $p = 0.03$) and creatinine ($r = 0.40$; $p < 0.01$). The relative distensibility of the carotid artery correlated with cholesterol ($r = -0.27$; $p < 0.01$), LDL-cholesterol ($r = -0.18$; $p = 0.01$), triglycerides ($r = -0.33$; $p < 0.01$) and glycemia ($r = -0.21$; $p < 0.01$). The carotid artery IMT correlated with cholesterol ($r = 0.18$; $p = 0.01$) and triglycerides ($r = 0.16$; $p = 0.03$).

Determinant factors of vascular parameters

On multiple linear logistic regression, the independent determinant factors of the vascular parameters, with their respective r values and significance level of the model, were as follows: (1) age and triglycerides for PWV ($r = 0.52$; $p < 0.01$) and relative distensibility of the carotid artery ($r = 0.65$; $p < 0.01$); age for IMT ($r = 0.42$; $p \leq 0.01$) and diameter ($r = 0.42$; $p < 0.01$); (2) SBP and DBP ($r = 0.65$; $p < 0.01$) for distensibility of the carotid artery; (3) creatinine ($r = 0.42$; $p < 0.01$) for carotid artery diameter (Table 5).

Correlation between the vascular parameters of the population studied

The results of the multiple linear logistic regression, with the respective r values and significance levels, were as follows: PWV ($r = 0.41$; $p < 0.01$) correlated with carotid artery IMT and distensibility; carotid artery diameter ($r = 0.26$; $p < 0.01$) correlated with distensibility (Table 5).

Discussion

This study showed the distribution of the values of the arterial parameters obtained through non-invasive methods in healthy individuals. Regarding the methodology to assess carotid artery properties, this is the first study carried out in Brazil in a healthy population, because ours is the only Brazilian institution to use that methodology already validated in other countries. In addition, the major clinical, anthropometric and laboratory variables correlated with the parameters obtained by using that methodology could be determined, as well as the relationships between the arterial parameters. It is worth noting that the participants had no clinical evidence of cardiovascular disease and used no medicaments; thus, reference values could be established, especially for the carotid artery assessment by use of radiofrequency. Regarding carotid artery parameters, our data comprise a database for the international registry of carotid artery IMT values[16].

The mean value of carotid-femoral PWV of the 210 individuals with no manifest clinical disease, whose mean age was 44 years, was 8.7 m/s, lower than that obtained in normal populations of other countries matched for the mean age[15]. Ethnical differences might explain the discrepancies, because the Brazilian population is highly mixed ethnically.

Table 3 – Distribution of pulse wave velocity (PWV), and carotid artery diameter, intima-media thickness (IMT) and relative distensibility according to age group in apparently healthy individuals

Age (years)	n	PWV (m/s)	Carotid artery diameter (µm)	Carotid artery IMT (µm)	Relative distensibility of the carotid artery (%)
≤ 30	34	7.60 ± 1.04	6268 ± 974	514 ± 119	7.53 ± 2.96
31-40	40	8.27 ± 1.28	6529 ±782	577 ± 147	5.91 ± 2.09
41-50	65	8.80 ± 1.82	6741 ± 948	608 ± 112	5.13 ± 1.72
51-60	35	9.22 ± 1.37	6903 ± 690	610 ± 78	4.16 ± 1.01
≥ 61	29	9.76 ± 1.66	6795 ± 682	718 ± 120	4.13 ± 0.75

Table 4 – Distribution of the values of the functional and structural parameters of large arteries according to blood pressure (BP) classification

BP classification	n	PWV (m/s)	CA diameter (µm)	Relative distensibility of the CA (%)	CA IMT (µm)
Optimal: < 120 x 80 mm Hg	92	8.39 ± 1.62*	6541 ± 769*	5.94 ± 2.52#	586 ± 143
Normal: 120/130 x 80/85 mm Hg	42	8.83 ± 1.67	6629 ± 895	5.35±2.60	614 ± 147
Borderline: 130/140 x 85/90 mm Hg	68	9.03 ± 1.60	6968 ± 900	5.02 ± 2.46	612 ± 144

** p < 0.05, optimal vs. borderline. CA: carotid artery; PWV: pulse wave velocity; IMT: intima-media thickness.*

Table 5 – Correlation between the vascular parameters and their determinants

	β	t	p value
PWV			
Age	0.54	7.10	< 0.01
Triglycerides	0.15	2.35	0.02
IMT	0.27	4.15	< 0.01
Distensibility	-0.26	-3.89	< 0.01
IMT			
Age	0.42	6.65	< 0.01
Distensibility			
Age	-0.55	-9.22	< 0.01
SBP	0.23	3.1	0.02
DBP	-0.27	-3.53	0.01
Triglycerides	-0.136	-2.26	0.03
Diameter			
Age	0.19	2.33	0.02
Creatinine	0.2	2.18	0.03
Distensibility	-0.25	-3.44	0.03

PWV: pulse wave velocity; IMT: intima-media thickness; SBP: systolic blood pressure; DBP: diastolic blood pressure.

In Brazil, a study carried out in the city of Vitória, Espírito Santo state, as part of the MONICA study[27], has shown PWV values associated with ethnicity, being higher among Afro-descendants. Our population showed no difference between white and non-white individuals, probably due to the lack of individuals with associated pathologies, such as found in the MONICA study[27] population. Afro-descendants more often have arterial hypertension, and, in our study, patients with that clinical condition were not assessed; this might justify the lack of ethnical difference in our data. The mean PWV in the population of the study from the city of Vitória was 9.2 m/s, while in ours it was 8.7 m/s.

The normal values obtained in our study can serve as reference for the implementation of PWV as an important tool to detect subclinical or pre-symptomatic lesions of target-organs in the routine assessment of patients. Only recently, a study involving 13 European centers and including data from 1,455 healthy individuals has established normal and reference values for PWV[15]. Most studies showing PWV as an important marker of cardiovascular risk in different populations, as well as the European study establishing normal and reference values for PWV, have used the same methodology applied in our study.

The functional and structural parameters of large arteries for normal and reference values can be represented in different ways. From the practical viewpoint, the pathophysiological findings that affect those parameters should be considered. Arterial stiffness increases with age and BP, which are the major determinants of PWV and carotid artery IMT, as shown in several studies and in ours. The normal values in our study were stratified by age decades and BP category, not including arterial hypertension. Based on the results of each age group and BP category, individuals at higher risk can be identified and placed in their respective normality range.

Although already acknowledged in several populations, the association between aging and the vascular properties assessed in this study is important to define the impact of aging on those properties in the Brazilian population. For example, in our population, the PWV values showed a 1.3-fold increase from the third to the sixth decade of life; in the European study[15], those values showed a 1.75-fold increase.

Blood pressure is another factor that plays a determinant role in the pathophysiology of the changes in vascular properties. This study did not assess any hypertensive patient, but categorized its participants based on their BP levels into optimal, normal and borderline, according to the recommendations of the VI Brazilian Guidelines on Hypertension[14]. It evidenced that individuals with borderline BP levels (between 130/85 mmHg and 140/90 mm Hg) had carotid-femoral PWV values significantly higher than those with optimal levels (< 120/80 mmHg). Similarly, individuals with borderline BP levels showed lower carotid artery distensibility than those with optimal BP levels. In the European reference study, the authors have also assessed patients with untreated arterial hypertension and have observed a progressive increase in PWV according to BP classification, and that increase was significantly higher in patients with stage II and III hypertension than in those of the other strata. Because of the large number of individuals assessed, they could be divided into age groups and BP categories, in a combined way. Thus, a 1.5-fold increase in

PWV could be observed in younger individuals with optimal BP levels and in the hypertensive elderly. Because of the smaller number of individuals in our study, that analysis could not be performed, but the same type of correlation might exist. Although the relationship between BP and PWV has been well known for almost one century, both our results and those of the European study suggest that the increase in PWV with BP is not merely attributable to the BP increase with age, but that the age effect is incremented by higher BP.

The lipid profile, especially triglyceride levels, has been related to both functional and structural parameters of large arteries. The role played by lipids in the properties of large arteries is still controversial. Based on our previous experience with patients with familial hypercholesterolemia, triglyceride levels were important determinants for both PWV and carotid artery distensibility[17,28].

Another important and unpublished finding of our study relates to the associations of the parameters obtained with the two methodologies for arterial assessment. The PWV measure was directly related to carotid artery IMT, showing a close correlation between a functional systemic change and a more localized structural change. In addition, an inverse and significant correlation was observed between carotid-femoral PWV and the relative distensibility of the carotid artery. That association of PWV and IMT had already been reported in a study with 564 individuals[29], half of whom were hypertensive, but, after correcting for other risk factors, that association disappeared, persisting only that between PWV and the presence of atherosclerotic plaques. In our study, the association remained significant even after correction for the major cardiovascular risk factors, and the presence of plaques was not assessed. In another study including 2,000 Finnish individuals[30], using different methodologies to assess PWV and IMT, the former was not significantly correlated with the second in the general population, only in older individuals. However, similarly to our study, PWV was inversely related to carotid artery distensibility, emphasizing the importance of the relationship between aortic stiffness and carotid functional properties. These data are important to show that two methods assessing similar functional properties, but in different ways, show equivalent results in a healthy population.

Study limitations

Comparing to other population studies, ours had a smaller number of individuals, which limited the establishment of criteria of normality. Part of those individuals did not undergo complete clinical and laboratory assessment, being excluded from the analysis. However, because most individuals underwent complete clinical and laboratory assessment for cardiovascular disease, that became a well-selected population with no evidence of associated disease; thus, the data originated from that population can be used as reference for comparison with populations with different pathologies.

Conclusion

In individuals without clinically manifest cardiovascular disease, aorta stiffness measured by using PWV increases with age, while the local functional parameters of the carotid artery are independently related to age and DBP. In that same population, the functional and structural vascular parameters are also associated, so that the carotid artery structure assessed by using IMT is directly related to aortic stiffness, while the latter is inversely related to the carotid artery functional property.

Those findings help to understand the factors related to the functional and structural measures of large vessels and how they correlate in the absence of manifest cardiovascular disease. Establishing those relationships is important for the clinical application of the methodology to assess vascular parameters in the presence of clinical diseases, contributing to use the method in our population.

Author contributions

Conception and design of the research: Tolezani EC, Mansur AJ, Bortolotto LA, Drager LF; Acquisition of data: Tolezani EC, Costa-Hong V; Analysis and interpretation of the data and Critical revision of the manuscript for intellectual content: Tolezani EC, Costa-Hong V, Bortolotto LA, Drager LF; Statistical analysis: Tolezani EC, Costa-Hong V, Bortolotto LA; Writing of the manuscript: Tolezani EC, Bortolotto LA; Capture patient: Correia G, Mansur AJ.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This article is part of the thesis of Doctoral submitted by Elaine Cristina Tolezani, from Faculdade de Medicina da Universidade de São Paulo.

References

1. Laurent S, Boutouyrie P, Asmar R, Gautier I, Laloux B, Guize L, et al. Aortic stiffness is an independent predictor of all-cause and cardiovascular mortality in hypertensive patients. Hypertension. 2001;37(5):1236-41.

2. NajjarSS, Scuteri A, Lakatta EG. Arterial aging: is it an immutable cardiovascular risk factor? Hypertension. 2005;46(3):454-62.

3. Cohn JN. Arterial stiffness, vascular disease, and risk of cardiovascular events. Circulation. 2006;113(5):601-3.

4. Sutton-Tyrrell K, Najjar SS, Boudreau RM, Venkitachalam L, Kupelian V, Simonsick EM, et al. Elevated aortic pulse wave velocity, a marker of arterial stiffness, predicts cardiovascular events in well-functioning older adults. Circulation. 2005;111(25):3384-90.

5. Liao D, Arnett DK, Tyroler HA, Riley WA, Chambless LE, Szklo M, et al. Arterial stiffness and the development of hypertension. The ARIC study. Hypertension. 1999;34(2):201-6.

6. Hashimoto J, Chonan K, Aoki Y, Nishimura T, Ohkubo T, Hozawa A, et al. Pulse wave velocity and the second derivative of the finger photoplethysmogram in treated hypertensive patients: their relationship and associating factors. J Hypertens. 2002;20(12):2415-22.

7. Safar ME, Levy BI, Struijker-Boudier H. Current perspectives on arterial stiffness and pulse pressure in hypertension and cardiovascular diseases. Circulation. 2003;107(22):2864-9.

8. Paini A, Boutouyrie P, Calvet D, Tropeano AI, Laloux B, Laurent S. Carotid and aortic stiffness: determinants of discrepancies. Hypertension. 2006;47(3):371-6.

9. Benetos A, Adamopoulos C, Bureau JM, Temmar M, Labat C, Bean K, et al. Determinants of accelerated progression of arterial stiffness in normotensive subjects and in treated hypertensive subjects over a 6-year period. Circulation. 2002;105(10):1202-7.

10. Weber T, Auer J, O'Rourke MF, Kvas E, Lassnig E, Berent R, et al. Arterial stiffness, wave reflections, and the risk of coronary artery disease. Circulation. 2004;109(2):184-9.

11. Bortolotto LA, Blacher J, Kondo T, Takazawa K, Safar ME. Assessment of vascular aging and atherosclerosis in hypertensive subjects: second derivative of photoplethysmogram versus pulse wave velocity. Am J Hypertens. 2000;13(2):165-71.

12. Bulpitt CJ, Rajkumar C, Cameron JD. Vascular compliance as a measure of biological age. J Am Geriatr Soc. 1999;47(6):657-63.

13. 2003 European Society of Hypertension-European Society of Cardiology guidelines for the management of arterial hypertension. Guidelines Committee. J Hypertens. 2003;21(6):1011-53.

14. Sociedade Brasileira de Cardiologia; Sociedade Brasileira de Hipertensão; Sociedade Brasileira de Nefrologia. VI Diretrizes brasileiras de hipertensão. Arq Bras Cardiol. 2010;95(1 supl.1):1-51.

15. Determinants of pulse wave velocity in healthy people and in the presence of cardiovascular risk factors: 'establishing normal and reference values'. The Reference Values for Arterial Stiffness' Collaboration. Eur Heart J. 2010;31(19):2338-50.

16. Engelen L, Ferreira I, Stehouwer CD, Boutouyrie P, Laurent S, on behalf of the Reference Values for Arterial Measurements Collaboration. Reference intervals for common carotid intima-media thickness measured with echotracking: relation with risk factors. Eur Heart J. 2012;34(30):2368-80.

17. O´Brien E, Petrie J, Littler W, de Swiet M, Padfield PL, Altman DG, et al. Short report: an outline of the revised British. Hypertension Society protocol for the evaluation of blood pressure measuring devices. J Hypertens. 1993;11(6):677-9.

18. O´Brien E, Mee F, Atkins N, Thomas M. Evaluation of three devices for self-measurementof blood pressure according to the revised British Hypertension SocietyProtocol: the Omron HEM-705CP, Philips HP 5332, and Nissei DS-175. Blood Press Monit. 1996;1(1):55-61.

19. Martinez LR, Miname MH, Bortolotto LA, Chacra AP, Rochitte CE, Sposito AC, et al. No correlation and low agreement of imaging and inflammatory atherosclerosis' markers in familial hypercholesterolemia. Atherosclerosis. 2008;200(1):83-8.

20. Guimarães GV, Ciolac EG, Carvalho VO, D'Avila VM, Bortolotto LA, Bocchi EA. Effects of continuous vs. interval exercise training on blood pressure and arterial stiffness in treated hypertension. Hypertens Res. 2010;33(6):627-32.

21. Drager LF, Bortolotto LA, Figueiredo AC, Silva BC, Krieger EM, Lorenzi-Filho G. Obstructive sleep apnea, hypertension, and their interaction on arterial stiffness and heart remodeling. Chest. 2007;131(5):1379-86.

22. Silva RC, Brunorio L, Giribela CR, Bortolotto LA, Wolosker N, Consolim-Colombo FM. Distances walked in the six-minute walk test: suggestion of defining characteristic for the nursing diagnosis Ineffective Peripheral Tissue Perfusion. Rev Lat Am Enfermagem. 2012;20(2):251-8.

23. Laurent S, Caviezel B, Beck L, Girerd X, Billaud E, Boutouyrie P, et al. Carotid artery distensibility and distending pressure in hypertensive humans. Hypertension. 1994;23(6 Pt 2):878-83.

24. Hoeks AP, Brands PJ, Smeets FA, Reneman RS. Assessment of the distensibility of superficial arteries. Ultrasound Med Biol. 1990;16(2):121-8.

25. Hoeks AP, Willekes C, Boutouyrie P, Brands PJ, Willigers JM, Reneman RS. Automated detection of local artery wall thickness based on M-line signal processing. Ultrasound Med Biol. 1997;23(7):1017-23.

26. Boutouyrie P, Bussy C, Lacolley P, Girerd X, Laloux B, Laurent S. Association between local pulse pressure, mean blood pressure, and large-artery remodeling. Circulation. 1999;100(13):1387-93.

27. Santos PC, Alvim Rde O, Ferreira NE, de Sá Cunha R, Krieger JE, Mill JG, et al. Ethnicity and arterial stiffness in Brazil. Am J Hypertens. 2011;24(3):278-84.

28. Miname MH, Ribeiro MS, Parga Filho J, Avila LF, Bortolotto LA, Martinez LR, et al. Evaluation of subclinical atherosclerosis by computed tomography coronary angiography and its association with risk factors in familial hypercholesterolemia. Atherosclerosis. 2010;213(2):486-91.

29. Zureik M, Temmar M, Adamopoulos C, Bureau JM, Courbon D, Thomas F, et al. Carotid plaques, but not common carotid intima-media thickness, are independently associated with aortic stiffness. J Hypertens. 2002;20(1):85-93.

30. Koivistoinen T, Virtanen M, Hutri-Kähönen N, Lehtimäki T, Jula A, Juonala M, et al. Arterial pulse wave velocity in relation to carotid intima-media thickness brachial flow-mediated dilation and carotid artery distensibility: the Cardiovascular Risk in Young Finns Study and the Health 2000 Survey. Atherosclerosis. 2012;220(2):387-93.