

ORIGINAL ARTICLE

Tonometric and Oscillometric Methods for Measurement of Central Blood Pressure Parameters: a Comparison in Patients with Borderline Hypertension or Stage 1 Hypertension

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Abstract

Background: Changes in arterial compliance are among the first changes detectable in hypertensive syndrome. Methods with good reproducibility as compared with the gold standard for identifying such changes are desirable in clinical practice.

Objectives: To compare central pressure measurements and arterial stiffness obtained by two non-invasive methods (tonometry and oscillometry).

Methods: This was a descriptive, cross-sectional study with a convenience sample of patients with borderline hypertension or stage 1 hypertension. Peripheral and central blood pressure measurements were obtained by tonometry (SphygmoCor®), considered the gold standard, and oscillometry (Mobil O'graph®). Comparisons of results were made by unpaired t-test, and p values < 0.05 were considered statistically significant.

Results: No difference was found in central pressure measurements obtained by SphygmoCor® (117 x 80.1 mmHg) compared with Mobil O'graph (112 x 81.4 mmHg). Mean augmentation index (AIx) was 26.1% and 21.3%, and mean pulse pressure (PP) amplification 10.7 mmHg and 10.0 mmHg by Sphygmocor® and Mobil O'graph®, respectively (p > 0.05). Mean pressure wave velocity (PWV), 8.4 m/s vs. 7.4 m/s (p = 0.013) and mean central pulse pressure, 37.7 mmHg and 30.9 mmHg (p = 0.013) were significantly higher by SphygmoCor® than Mobil O'graph®.

Conclusion: Values of central systolic blood pressure, AIx and pulse pressure amplification obtained by oscillometry were not statistically different compared with tonometry; values of PWV and cPP, however, were underestimated by oscillometry. (Int J Cardiovasc Sci. 2020; 33(2):145-150)

Keywords: Hypertension; Risk Factors; Blood Pressure; Vascular Stiffness.

Introduction

Guidelines for the management of hypertension have recommended an early diagnosis and treatment of arterial hypertension as a fundamental strategy to reduce the occurrence of cardiovascular events.¹⁻³ In this regard, the use of biomarkers can increase the accuracy of the diagnosis, especially in patients with borderline hypertension and in patients with stage 1

hypertension. In these patients, in up to 18% of the cases, cardiovascular risk is underestimated by the conventional risk stratification model.^{4,5}

The best biomarkers for risk stratification in hypertensive patients are intima-media thickness (IMT) of common carotid artery and pulse-wave velocity (PWV).^{1,2,6,7} There is strong evidence that PWV is a method capable of identifying subclinical lesions and accurately determining the risk stratification for

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occurrence of cardiovascular events. For hypertensive patients, this biomarker is mainly indicated at initial stages of blood pressure (BP) elevation and in those at low or moderate cardiovascular risk.⁸⁻¹⁰

Several non-invasive devices have been developed aiming at estimating central blood pressure and other parameters of arterial stiffness from measurements of peripheral arteries (radial, brachial and carotid arteries), using mathematical algorithms and methods of calibration or estimation. These devices have allowed the determination of several parameters that until then were obtained only by invasive methods.¹¹

Among the non-invasive methods, arterial tonometry for measurement of PWV is considered the gold-standard method and is validated for intra-arterial pressure measurements. However, electronic tonometers are expensive and technically more difficult to be use. In contrast, oscillometric methods are validated, and faster and easier to perform, providing a better cost-benefit relationship.¹²⁻¹⁵

Our objective was to statistically compare results obtained by two non-invasive methods – tonometry and oscillometry – in patients with stage 1 hypertension and patients with borderline hypertension in Brazil.

Methods

This was a descriptive, cross-sectional study, conducted in patients attending the *Liga de Hipertensão Arterial da Universidade Federal de Goiás (LHA/UFG)*, a program aiming at providing a comprehensive, multidisciplinary care to patients with cardiovascular diseases. The study was approved by the ethics committee of the General Hospital of the Federal University of Goiás (approval number 000985/2016) This is one of the sub-studies of the original project entitled “*Correlação entre Valores Obtidos na Medida Central da Pressão Arterial com a Espessura das Camadas Íntima e Média das Artérias Carótidas em Pacientes com Pressão Arterial Sistêmica Limitrofe ou Hipertensos Estágio 1*” (Correlation of Central Blood Pressure with intima-media thickness of common carotid artery in patients with borderline hypertension or stage 1 hypertension”.

Between March 2016 and July 2016, a total of 1,500 medical records of adult patients attending the LHA/UFG were reviewed, and 240 were selected. The selection was based on the data registered during this period, including BP values measured at the last visit. BP was considered as borderline or stage 1 hypertension according to the

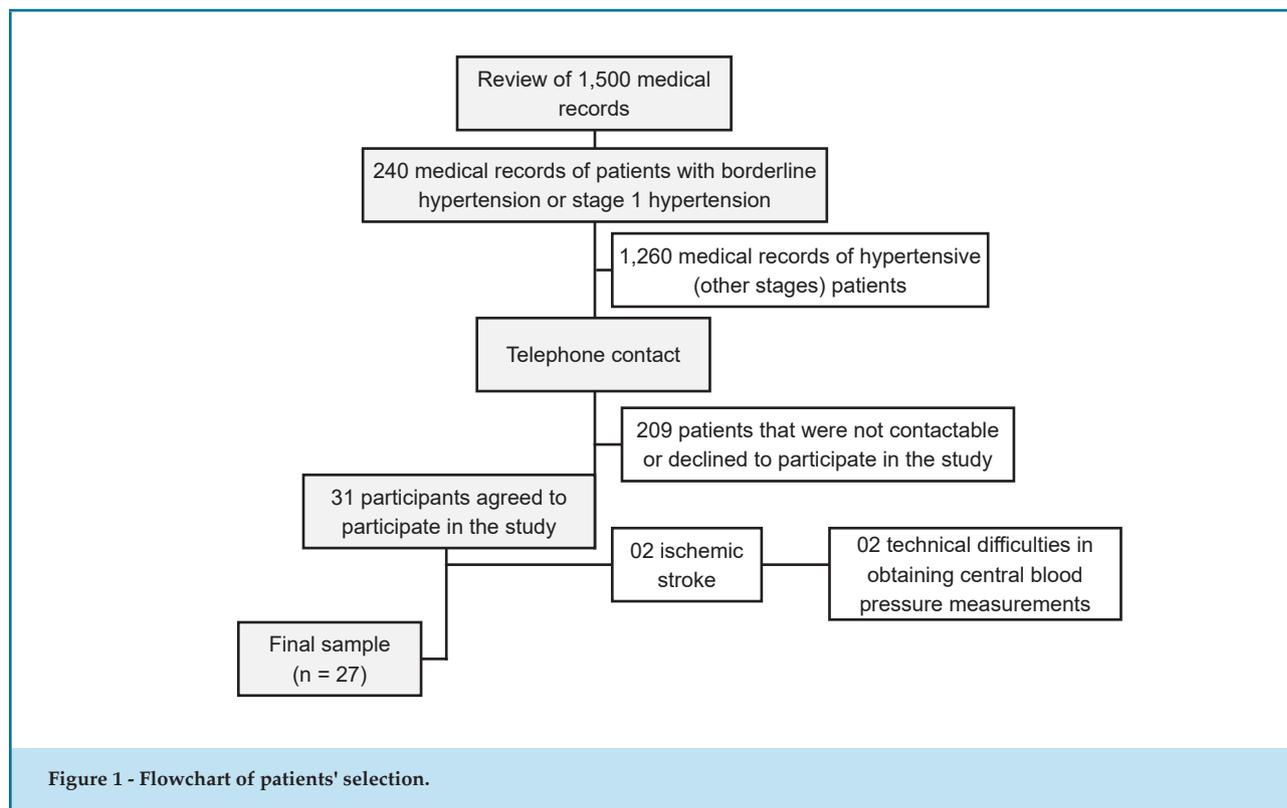
Brazilian guidelines of arterial hypertension.¹ Patients participating in other research protocols for less than one year and patients with comorbidities – diabetes mellitus, end-stage chronic diseases (chronic renal failure and congestive heart failure), cardiovascular diseases (including coronary artery disease and stroke) were excluded. We intended to select patients at low cardiovascular risk (Figure 1).

At a second stage, telephone contact attempts to the patients were made, using the telephone numbers registered on the medical records. When patients could not be contacted, new attempts were made by the Medical Registry. Three telephone calls were made in different days and times. When telephone contact was successful, patients were invited to participate in the study, and a visit was scheduled at the LHS for those who accepted to participate.

Two-hundred forty medical records were first selected. After screening for the criteria described above and after the telephone contacts were made, the final sample consisted of 31 patients who agreed to participate in the study. Two of these were excluded for the presence of previous cardiovascular event (ischemic stroke) after the review of the medical records, and two were excluded for technical difficulties in obtaining central BP measurements (one using the SphygmoCor® and the other using the Mobil O'Graph®), because of the presence of cardiac arrhythmia. Thus, the convenience sample was composed of 27 patients.

All patients signed the informed consent form, and then completed a form on anthropometry, life habits, and history of past diseases. Measurements of peripheral and central BP were then taken, registered on the study form and then filed in an electronic database.

Peripheral BP (PBP) was measured at the office following the Brazilian Guidelines of Hypertension recommendations.¹ Measurements were taken using semiautomated devices (OMRON®, modelHEM-705CP, validated by international institutions and recommended for epidemiological applications.¹⁶ Central blood pressure was measured by trained observers, using different methods. The first method consisted of applanation tonometry (portable pressure transducer or sensor), attached to a dedicated software for collection and analysis of the data. The results obtained, as well as the last PBP (measured at the physician's office) were inserted into the database. For PBP readings, the transducer was placed on the radial artery of patients in



supine position. Data were obtained by transfer function for central systolic blood pressure (cSBP) central diastolic blood pressure (cDBP), central pulse pressure (cPP), pulse pressure (PP) amplification and augmentation index (AIx). For measurement of pulse wave velocity (PWV), the transducer was placed on femoral and carotid arteries, and the velocity at which pressure moved down this distance was determined in centimeters and multiplied by a correction factor of 0.8.^{2,17}

The second method was a validated oscillometric method using the Mobil O'Graph® BP monitor. In this method, central BP is estimated by a mathematical algorithm derived from PWV of the brachial artery. This method also allowed the estimation of cSBP, CDBP, cPP, PP amplification, AIx and PWV. Central BP measurements were made with patients in sitting position; data were analyzed with the Mobil O'Graph monitor analysis software.¹⁴

Statistical analysis

Statistical analysis of the data was made using the Stata software, version 14.0. First, a descriptive analysis was performed; qualitative variables were expressed

as absolute and relative frequencies, and quantitative variables as mean, standard deviation and confidence interval. The Shapiro-Wil test was used to test normality of data distribution. Comparisons of peripheral and central measures obtained by the two different methods were made by unpaired t-test. Statistical significance was set at $p < 0.05$.

Results

Twenty-seven patients aged 50.8 ± 15 years participated in the study, most of them (63%) were women. Most patients (59.3%) were physically inactive, with mean body mass index (BMI) of 27.3 ± 4.8 Kg/m² (95%CI 25.4 - 29.3) (Table 1).

Regarding pBP measurements, four patients were classified as borderline hypertensive and 23 as hypertensive; 81.5% of them used at least one anti-hypertensive agent.

Central SBP (128 mmHg) was significantly lower than pSBP, both by tonometric (117.7 mgHg) and oscillometric (112 mmhg) methods ($p < 0.006$ and $p < 0.001$ respectively). No statistically significant difference was observed for the diastolic component of BP (Table 2).

Comparisons between Sphygmocor® and Mobil O'Graph®, the methods used for determination of cBP parameters, revealed no statistical difference for PAsC, AIx and PP amplification, but statistical difference was observed for PWV and cPP (Table 3).

Table 1 - Lifestyle characteristics of the study group (n = 27)

Variable	n	%
Physical exercise (frequency)		
Regular	11	40.7
Irregular	01	3.7
None	15	55.6
Alcohol consumption (frequency)		
Never	17	63.0
Rarely	03	11.1
< 4x/week	05	18.5
> 4x/week	02	7.4
Smoking load (pack-years)		
None	25	92.6
< 5	01	3.7
> 20	01	3.7

Table 2 - Comparison of peripheral blood pressure measurements obtained by OMRON 705CP with the same measurements obtained by SphygmoCor® and Mobil O'Graph® (n = 27)

Variable	Mean	SD	95%CI	p
pSBP	128.4	13.4	123.0-133.7	
cSBP (SphygmoCor®)	117.7	14.0	112.1-123.2	0.006*
cSBP (Mobil O'Graph®)	112.0	10.1	108.0-116.0	0.001*
pDBP	76.1	10.5	71.9-80.2	
cDBP (Shpygmocor®)	80.1	10.6	75.9-84.3	0.172*
cDBP (Mobil O'Graph®)	81.4	10.5	77.2-85.5	0.070*

SD: standard deviation; CI: confidence interval; pSBP: peripheral systolic blood pressure; cSBP: central systolic blood pressure; pDBP: peripheral diastolic blood pressure; cDBP: central diastolic blood pressure. * Compared with OMRON 705CP.

Discussion

Arterial stiffness and cBP are better predictors of cardiovascular events compared with peripheral parameters of BP, especially in the initial stages of hypertensive disease and in hypertensive patients at low and moderate risk,^{5,9,18,19,20} and considered as important tools in restratification of these patients.^{1,2}

The values of peripheral BP (128.4 s 76.1 mmHg) found in our sample are consistent with those of patients in the initial stages of hypertensive disease.

Analysis of BP in large arteries (rather than peripheral values) showed that, corroborating previous studies, an amplification of systolic pressure occurs, from central to peripheral arteries, and diastolic pressure tended to remain unchanged.²¹ Central SBP determined by tonometry was 10.7 mmHg lower than pSBP (p = 0.006), whereas by oscillometry, this difference was

Table 3 - Comparison of central blood pressure measurements obtained by SphygmoCor® with the same measurements obtained by Mobil O'Graph® (n = 27)

Variable	Mean	SD	95%CI	p
cSBP (SphygmoCor®)	117.7	14.0	112.1-123.2	0.09
cSBP (Mobil O'Graph®)	112.0	10.1	108.0-116.0	
cDBP (SphygmoCor®)	80.1	10.6	75.9-84.3	0.654
cDBP (Mobil O'Graph®)	81.4	10.5	77.2-85.5	
cPP (Shpygmocor®)	37.7	12.6	32.7-42.7	0.013
cPP (Mobil O'Graph®)	30.9	5.4	28.7-33.0	
PPA (Shpygmocor®)	10.7	5.7	8.4-12.9	0.619
PPA (Mobil O'Graph®)	10.0	3.8	8.5-11.5	
AIx (Shpygmocor®)	26.1	18.3	18.9-33.4	0.244
AIx (Mobil O'Graph®)	21.3	11.2	16.9-25.7	
PWV (Shpygmocor®)	8.4	1.6	7.8-9.1	0.013
PWV (Mobil O'Graph®)	7.4	1.4	6.8-7.9	

SD: standard deviation; CI: confidence interval; cSBP: central systolic blood pressure; cDBP: central diastolic blood pressure; cPP: central pulse pressure; PPA: pulse pressure amplification; AIx: augmentation index; PWV: pulse wave velocity

16.4 mmHg (0.001). No statistical difference was found for the diastolic component of BP (Table 2).

It is of note that, compared with peripheral pressures, central BP shows a better correlation with clinical outcomes. This is probably explained by the fact that central pressures have lower variability, and from the pathophysiological point of view, central pressure reflects the levels of tension on target organs.²²⁻²⁶ In the comparison between central BP values obtained by tonometry and by oscillometry, no difference was found for cSBP, cDBP, PP amplification, and AIx, but differences were found for cPP (37.7 mmHg and 30.9 mmHg, $p=0.013$) and PWV (8.4 m/s and 7.4 m/s, $p=0.013$). These findings also corroborate previous findings showing a tendency of the oscillometric method in underestimating parameters of cBP.^{12,14,15}

A study with 320 patients comparing an oscillometric (ARCSolver - Mobil O Graph®) method with the tonometric (SphygmoCor®) method, the results of most parameters agreed with those obtained by tonometric method.²⁷ In another study with 89 patients, the authors also reported good reproducibility between the methods and suggested that oscillometry should be considered in everyday clinical practice, as it is an easy-to-perform test, with good cost-benefit relationship.²⁸

A guideline on protocols, equipment and non-invasive methods for estimation of central BP, published by the Artery Society in 2017, showed that, compared with intra-arterial BP measurement and the non-invasive tonometry method, the oscillometric method tend to underestimate PWV measurements, which should be considered in the use of this method.²⁹

More recently, a risk score (SAGE score) has been validated, using clinical criteria to identify hypertensive patients at higher risk for developing elevated arterial stiffness. In this patients, analysis of central BP would be indicated,³⁰ i.e., there is a current thinking of the scientific community that the method should be incorporated in cardiovascular risk stratification as an effective tool to early detect patients at higher risk.

Despite the small sample size, we believe that our main objective in this study, to compare central hemodynamics indices obtained by different methods in patients at low cardiovascular risk, was achieved.

To our knowledge, this is the first nation-wide study to evaluate the reproducibility of the oscillometric method in comparison with tonometric method in patients with borderline BP or patients with stage 1

hypertension, that may contribute to the advance, debate and implementation of this tool into clinical practice.

Conclusion

The parameters of central BP and those that reflect arterial compliance, particularly PWV, show better correlation with cardiovascular outcomes in hypertensive patients than peripheral BP measurements.

The use of non-invasive methods (tonometry and oscillometry) were validated for intra-arterial BP measurements of these parameters. Although tonometry is considered the gold standard among non-invasive methods, oscillometry has good reproducibility and may be considered a promising instrument to be used in clinical practice.

Author contributions

Conception and design of the research: Barroso WKS, Vitorino PVO. Acquisition of data: Barroso WKS, Gonçalves CF, Berigo JAC, Melo MA, Oliveira ACA, Vitorino PVO. Analysis and interpretation of the data: Barroso WKS, Gonçalves CF, Berigo JAC, Vitorino PVO. Statistical analysis: Vitorino PVO. Writing of the manuscript: Barroso WKS, Gonçalves CF, Berigo JAC, Melo MA, Vitorino PVO. Critical revision of the manuscript for intellectual content: Barroso WKS, Gonçalves CF, Berigo JAC, Melo MA, Oliveira ACA, Lelis ES, Sousa WM, Rezende JM, Jardim TV, Sousa ALL, Jardim PCBV, Vitorino PVO.

Potential Conflict of Interest

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

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Study Association

This article is part of the thesis of master submitted by Milena Andrade Melo, from Universidade Federal de Goiás.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the *Hospital das Clínicas da Universidade Federal de*

Goiás under the protocol number 000985/2016. All the procedures in this study were in accordance with the 1975

Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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