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Original Research

Comparison of Prevalent Hypertension by Aortic versus Brachial Blood Pressure Criteria for - A Pulse Wave Analysis Based Study from Adults of a City of West India

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Abstract

Background: Disparities exist in aortic blood pressure (aBP) and brachial blood pressure (bBP) and between aortic (AH) versus brachial hypertension (BH). While the former is superior, it is studied scarcely. Pulse wave analysis (PWA) provides objective and simultaneous measurement of both blood pressures to determine AH and BH. Using PWA, we compared prevalent AH and BH in a sample adult population.

Methodology: By oscillometric PWA (Mobilograph, IEM, Stolberg, Germany), 1187 participants with age >18 years were evaluated. Simultaneous aBP and bBP were recorded by standard PWA protocol and prevalence of AH and BH was estimated. Age and gender-based subgroups were compared for aortic versus brachial BP differences. Prevalence of Hypertension, Isolated Systolic Hypertension, and Pulse Pressure ≥40 was compared between aortic versus brachial criteria.

Results: Significant differences were seen between bBP and aBP across all age groups and in both genders, especially for the younger age groups. As compared to bBP, aBP gave a higher fetch for prevalent hypertension and a lower fetch for prevalent Isolated Systolic Hypertension (ISH). bPP ≥40 was sensitive but not specific as a surrogate for aPP ≥ 40.

Conclusions: Across ages 18-65 in either sex, disparities exist between bBP and aBP mostly for SBP and PP with significant differences in prevalent Hypertension, Isolated Systemic Hypertension, and high pulse pressure. It reaffirms disparities of aBP and bBP and diagnosed brachial or central hypertension based on them with the need for further work.

Keywords: Age; Blood Pressure; Correlation; Gender; Hypertension.

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Introduction

Hypertension is one of the familiar encounters to a family physician who uses brachial blood pressure (bBP) as a routine tool, but it has some limitations.[1] Aortic BP (aBP) is superior, discrete & direct to heart [2], and is better associated with cardiovascular morbidity and mortality. Mobilograph-based oscillometric pulse wave analysis (PWA) provides validated non-invasive, objective, and simultaneous measurements of aBP and bBP [3] and the same can be practiced even at a primary care level. There is emerging evidence about the use of aBP for clinical use [4] more so in young middle-aged individuals with Isolated Systolic Hypertension (ISH).[5] Despite such a high prevalence of hypertension, lacunae exist about the relationship between bBP versus aBP and brachial versus aortic hypertension in our population.[6] Before it can be clinically used at the primary care level, the correlation between these two BPs and the hypertension defined by them should be studied which was the aim of this study.

Methodology

Study setup and sample.

An observational study was conducted in an outdoor community setting of the city of Gujarat, India under the guidance of the Medicine and Physiology department of a government medical college attached to a tertiary care teaching government hospital. Prior permission was obtained from the Medicine and Physiology departments of the government medical college, Gujarat, India while ethical approval was obtained from the institutional review board of the GMC Gujarat with the number IRB (HEC) no.877/2019. Written informed consent from participants undergoing the study was taken and they were informed about the benefit, objectivity, and aim of this study. In this study, 1186 apparently healthy participants were recruited from the city, chosen by stratified sampling with the following age groups (18-24,25-34,35-44,45-54,55-65) and gender-based groups. The inclusion criteria for the study participants were age between 18 to 65 years, gender of either sex, written informed consent, no history of cardiovascular disease, and non-use off any medications affecting the autonomic nervous system. Out of a pool of 1210 recorded PWA, 24 participants were excluded post hoc showing irregular pulse waves or poor quality of data of PWA.

Pulse wave analysis – Instrument and method

Our research tool is the same as used in previous PWA studies [3] [7] [8] and described here. A portable, personal computer attached, calibrated, and validated instrument Mobil-O-Graph (IEM Gmbh, Stolberg, Germany) of the Physiology department was used to record brachial pressure pulse wave. It undergoes oscillometric pressure PWA as per protocol designed by the European Society of Hypertension (ESH) and has proven to have excellent accuracy in children, adolescents, and young adults as recently reported [9] by an invasive validation study. The measurement protocol, as published elsewhere [3] [7] [8], is as below. A blood pressure cuff of appropriate size (mid-arm circumference: 20–24 cm = small size, 24–32 cm = medium size, 32–38 cm = large size) was chosen based on measured mid-arm circumference and applied to left arm using a standard protocol. All readings were taken after the rest of 10 min, in the postabsorptive phase while subjects avoided smoking or alcohol for 12 hours before measurement, in a calm room without external influences or avoiding arm movement. Pressure oscillations are generated by brachial arterial pulsation, which is transmitted to the bBP cuff and measured by the transducer to be fed into the microprocessor. Computerized software records pulse waves from the brachial artery and derive central aortic pulse waves by a validated generalized transfer factor. It point-based and area-based analysis by computer was applied to derive various cardiovascular parameters.

Pulse wave analysis parameters

The following measured study parameters were included for evaluation: Heart rate (HR), Body Mass Index (BMI), brachial blood pressure (bBP), brachial systolic blood pressure (bSBP), brachial diastolic blood pressure (bDBP), brachial pulse pressure (bPP), mean brachial blood presurre (bMBP), central

blood pressure cBP – central systolic blood pressure (cSBP), central diastolic blood pressure (cDBP), and central pulse pressure (cPP).

Defining norms: Values for the following study parameters were based on the European Society of Hypertension and European society of cardiology (ESH/ESC) guidelines [10]**.** Brachial hypertension- brachial BP –systolic ≥140 and diastolic ≥ 90 mm Hg; Central hypertension- aortic BP systolic ≥130 and diastolic ≥ 90 mm Hg; Isolated brachial systolic hypertension- brachial systolic BP ≥ 140 mm Hg and Isolated central systolic hypertension - aortic systolic BP ≥ 130 mm Hg

Statistical evaluation:
The data was entered into and processed by Excel spreadsheet. Numerical data were shown as mean ± standard deviation until specifically indicated and qualitative data were shown as number (percentage). Bio-statistical calculations were performed using QuickCalcs of GraphPad software (demo version free software of GraphPad Software, Inc. California, USA). Numerical data were compared by unpaired t-test or Mann–Whitney test for two groups. The Chi square test was used to analyze contingency tables and qualitative data distribution. Normality tests were used to find specificity, sensitivity, and predictive values for bPP against aPP, using cut-off value 40. The statistical significance level chosen was P value < 0.05.

Results

In both genders and across all age groups, comparison between aBP and corresponding bBP showed higher bBP than aBP, of which statistical significance was present for SBP and PP. (Table 1). The Prevalence of brachial versus aortic hypertension (89 vs. 85 positives for hypertension) did not statistically differ in study participants while using bBP or aBP respectively. (Table 2) the Point prevalence of Isolated Systolic Hypertension was statistically significantly higher for Brachial Isolated Systolic Hypertension than Aortic Isolated Systolic Hypertension (44 vs. 27, p-0.04). Considering aBP as the gold standard; there were a 1.65 times odds risk of over diagnosing Isolated Systolic Hypertension by bBP criteria as compared to aBP criteria. (Table 3) With PP≥40 as a risk/positive outcome and aBP as the gold standard, bBP≥40 was 95% sensitive, only 7% specific that had less positive (24%) than negative (77.8%) predictive value. (Table 4)

Table 1: Age and gender-wise comparison between bBP and corresponding aBP (mean ± SD)

Age group	**Male subgroup**			**Female subgroup**		
SBP	**aortic**	**brachial**	**p-value**	**aortic**	**brachial**	**p-value**
18-24	110.54±11.10	124.21±11.49	***<0.00001***	104.95±12.28	116.41±10.54	**<0.00001**
25-34	112.26±10.18	112.67±11.20	**<0.00001**	108.66±9.76	117.05±10.03	**<0.00001**
35-44	114.35±16.57	124.05±14.28	**0.00002**	111.67±12.96	120.08±15.23	**<0.00001**
45-54	115.64±12.75	123.97±13.69	**<0.00001**	115.85±13.52	124.58±14.81	**<0.00001**
55-65	124.55±17.05	133.47±18.47	**0.01**	124.16±16.85	132.81±17.96	**0.007**
DBP	**aortic**	**brachial**	**p-value**	**aortic**	**brachial**	**p-value**
18-24	81.05±9.84	79.08±8.87	**0.04**	78.66±7.84	76.54±9.75	**0.049**

25-34	79.77±10.87	78.59±10.52	0.43	79.76±9.44	78.37±9.15	0.41
35-44	82.56±11.59	82.97±11.86	0.35	80.2±11.09	78.96±10.86	0.15
45-54	85.21±10.85	83.81±10.62	0.29	82.95±12.02	81.53±12.17	0.31
55-65	90.45±11.76	88.77±11.53	0.46	85.77±12.54	84.13±12.55	0.47
PP	**aortic**	**brachial**	**p-value**	**aortic**	**brachial**	**p-value**
18-24	30.22±8.13	45.24±11.43	**<0.00001**	26.87±6.69	39.37±8.66	**<0.00001**
25-34	32.22±7.57	44.58±11.21	**<0.00001**	28.74±6.99	38.68±8.43	**<0.00001**
35-44	30.62±9.08	40.69±11.11	**<0.00001**	31.07±8.28	41.02±12.42	**<0.00001**
45-54	30.34±7.82	39.98±9.71	**<0.00001**	33.04±8.95	43.19±10.59	**<0.00001**
55-65	35.11±12.41	44.2±12.53	**0.0001**	38.39±13.23	48.63±14.99	**0.0009**

Table 2: Comparison of the difference in the prevalence of hypertension (HTN) by brachial v/s aortic BP criteria

BP criteria	HTN +	HTN -	total	statistic
Aortic BP	89	1097	1186	X^2- 0.10
Brachial BP	85	1101	1186	p -0.76

Odds ratio- 1.65, 95% CI -1.02 2.69, p-value-0.0425

Table 3: Comparison of difference in prevalence of Isolated systolic hypertension (ISH) based on brachial v/s aortic BP criteria

BP criteria	ISH +	ISH -	total	statistic
aortic	27	1159	1186	X^2- 4.20
brachial	44	1142	1186	p -***0.04***

Odds ratio- 1.65, 95% CI -1.02, 2.69, p-value-0.0425

Table 4: Calculation of specificity and sensitivity of bPP compared to aPP (as gold standard) with cut-off 40 to diagnose prevalent risk for pulsatile flow-induced damage (n=1186)

	aPP ≥ 40 +	aPP ≥ 40 -	Total	Statistics
bPP ≥ 40 +	77	245	322	Sensitivity -95.06%, Specificity-6.96%
bPP ≥ 40 -	4	860	864	PPV- 23.9%, NPV- 77.8%

+ is present, - is absent

Discussion

The gold standard bBP has some limitations like the disparity between the properties of the brachial and aortic artery [6]; the distance of the brachial artery from the heart as compared to the aorta which is close to the heart [6]; the subjectivity of calibration associated with brachial blood pressure measurement devices and pressure amplification especially with systolic component [11]. The lack of availability of a device which simultaneously measures both brachial and aortic BP has been a major challenge. A century ago, before the invention of the riva-roci cuff, PWA was the gold standard for assessing hemodynamic parameters.[12] It has lost its place to the sphygmomanometer since then. With the surge of hypertension, even for people at a young age and for mainly SBP, it is time to look back to PWA. The mobilograph is one such device based on PWA which was used on a sample population to study the relationship between brachial and aortic BP.

The major outcomes of this study were disparities in brachial and central pulsatile BP (SBP and PP) than stable BP (DBP) in participants of 18-65 years. Differences ensued between bBP and aBP which was larger for SBP and PP. As compared to bBP criteria, aBP criteria gave better fetch for ISH, but not for Essential Hypertension. Brachial ISH significantly outnumbered central ISH at point prevalence. Pulse pressure ≥40 gave high sensitivity (95%) but low specificity (6%) for brachial than to aortic values measured simultaneously by PWA. This is in line with studies [5] [13] [14] [15] [16] done elsewhere but reported first in our population. aBP is scarcely measured owing to the unavailability of measuring devices and validity issues. Antihypertensive medications have a differential effect on the aorta [17] which is more elastic than the brachial artery which is more muscular in line with this concept. The discrepancy was significantly higher in the age group 18-24 and to some extent 25-34 years, so with further studies we can test the hypothesis whether it is evident on a larger scale or not. This is need is more when most BP cut criteria consider 65 years age as cut off and 18-35 years have no specific cut-offs; and in light of the raising prevalence of hypertension at this young age group than before.

These disparities can be explained by the arterial stiffness gradient that is reversed with ageing. [18] Pulse wave velocity of elastic Aortic artery increases more than muscular arteries like the brachial Artery.[18] Therefore with ageing, the gradient of arterial stiffness reverses between elastic and muscular arteries. There are three underlying changes [18] responsible for it; impedance mismatch turning to match, protective wave reflection converting to reduced wave reflection, and change in nature of microvasculature blood flow from smooth to pulsatile. With increased aortic stiffness, aSBP gets disparities from bSBP [19] so that bSBP is higher than aSBP. It was revealed by delta values between simultaneously measured aBP and bBP which were significant for both SBP and PP. The use of central blood pressure improves cross-classification of hypertension mainly for isolated systolic hypertension [20] that we noticed in our sample population not aged >65 years. This also supports the observation [21] that central BP can better predict the development of hypertension in the general population, and it can possibly be a significant predictor of new-onset hypertension in individuals without hypertension. Single office measurement of aBP is known to better detect masked hypertension [22] like our study that showed the same. Though there was a low prevalence and lesser significance it can be further explored in the elderly and those with CVD risk. The least disparity was observed for DBP which is a stable component, in accordance with the study previously reported [13] proving it is the reliable type of blood pressure across arterial trees. Pulse pressure is a potent risk predictor of cardio-vascular health [23] with PP≥40 being taken as a significant risk factor for target organ damage to downstream organs with high capillarity-like brain, kidney, and heart. A routine sphygmomanometer provides bBP but not aBP so such risk factors cannot be assessed centrally at the aortic level. On comparing the prevalence of high aPP versus bPP, the former was found not to be a surrogate of the later with high sensitivity (95%) but poor specificity (7%) and lesser positive predictive value (24%). So, it suggests that the use of only bPP cut-off 40 will give a false high prevalence. This is more important in hypertensives where aPP≥40 leads to the risk of stroke, ischemic heart disease, and nephropathy.[24]

Central over peripheral BP is an emerging issue in hypertension research [25], more so considering the alarming rise of hypertension [26] in India and Asia. Central hypertension is a non-negotiable cardiovascular disease risk factor [27]. It is therefore desirable to improve central blood pressure measurement which is not a routine practice currently. [28] The guidelines for the diagnosis of hypertension have differences [29] and aortic BP-based aortic hypertension can be considered as an important parameter to measure in evaluation of these differences. The bBP to aBP disparities are also evident in newly diagnosed hypertensives [30] as we have shown in this study which had a non-hypertensives' population. The advantages of aBP over bBP in the evaluation of hypertension, especially with systolic blood pressure, pulse pressure and isolated systolic hypertension were shown in this study. There is a need for further studies and vertical follow-up.

Our study was limited by single rather than 24 hr PWA, lack of biomarkers of vascular aging, and many confounders prevailing among the population, yet it hints at a study in young and middle-aged populations more so with ISH to consolidate our findings. Similarly, considering the huge disparity between brachial and aortic PP, there is a scope for studying this further, using a device like a Mobilograph that allows non-invasive discrete measurement of both BPs simultaneously.

Conclusion

Differences were found between aBP and bBP across 18-65 years of age for pulsatile more than continuous components of blood pressure. The use of aBP is suggested to improve risk stratification for total organ damage and diagnosis of isolated systolic hypertension. It calls for further study for evaluation and re-affirmation of the advantages of aBP over bBP in non-elderly Indian population.

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