

Incorporating Central Aortic Pressure Monitoring in the Care of Hypertension in the Black Population

Background

Racial disparities exist in many disease states that have multifactorial explanations. Broadly, explanations for disparities can be divided into those related to genetics, behavior, and sociopolitical issues. For decades, the disproportionately high prevalence and impact of hypertension, heart disease and stroke in African Americans has been characterized. The objective of this document is to briefly summarize the socioeconomic burden of hypertension in the black community and review the role that noninvasive monitoring of central aortic blood pressure (BP) may have in clinical management.

Epidemiology of Hypertension in Black Populations

Multiple publications indicate that elevated BP has an earlier onset and is higher for black compared to white populations. The prevalence of stage 2 hypertension (defined as brachial systolic BP >140 mmHg and/or diastolic BP > 90 mmHg) is particularly high in black men but also elevated in black women relative to white or Mexican American men across different time frames as documented in a report from the Centers for Disease Control and Prevention (CDC) (Table 1).^{1,2}

Table 1. Prevalence of elevated blood pressure by race/ethnicity and sex 20-74 years of age, for selected years.²

Race/Sex	1988-1994	1999-2002	2003-2006
African American men	30.3%	28.2%	26.5%
White men	19.7%	17.6%	17.4%
Mexican American men	22.2%	21.5%	15.3%
African American women	26.4%	28.8%	23.9%

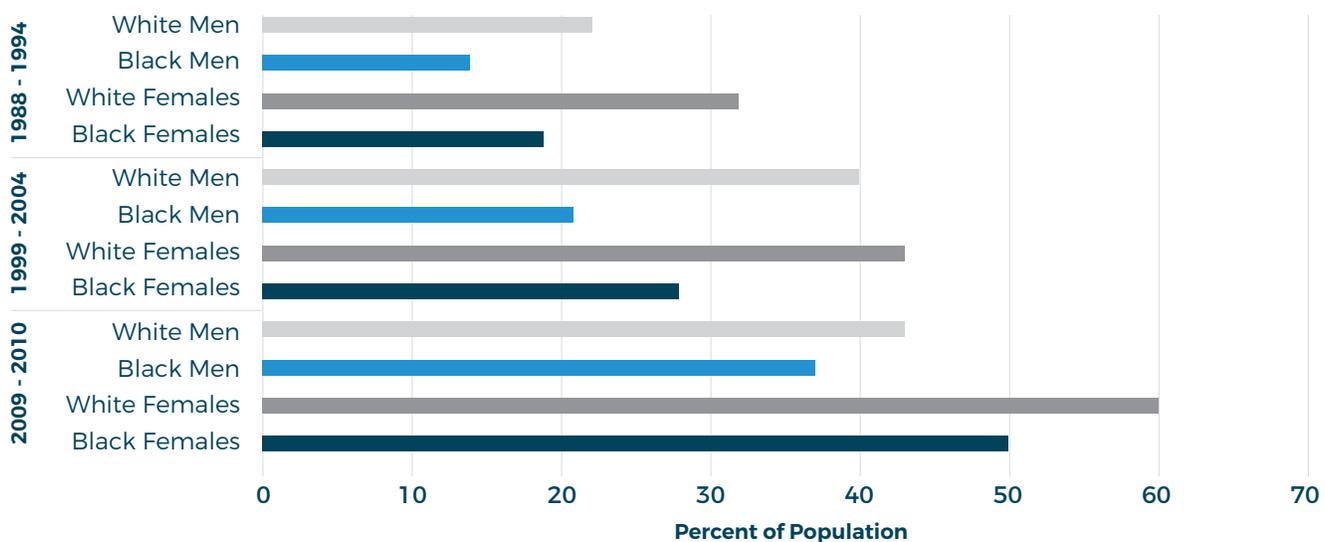
Across populations, hypertension awareness remains a concern and contributes to overall morbidity; however, the aforementioned CDC report noted that awareness in blacks did not show disparities and actually showed relatively high awareness in black women.¹ Despite awareness and similar approaches to treatment, incidence of adverse outcomes related to hypertensive disease (i.e., death, renal disease, cardiac disease, and stroke) in both black men and women have been substantially higher relative to other populations.^{1,3}

In a long-term study with 20 years of follow-up in subjects between the ages of 18 and 30 years, the cumulative incidence of systolic heart failure was higher in black adults (1.1% in black women and 0.9% in black men) compared to white adults (0.08% in white women and 0% in white men; $p < 0.001$ for blacks vs. whites) and was directly related to hypertension.⁴

In a review publication, Lackland noted the following for black adults in the United States:³

- Hypertension attributable risk and 30-year mortality was 23.8% in white men compared to 45.2% for black men. Differences were 18.3% vs. 39.5% for white women compared to black women.
- Stroke mortality risks are two-fold greater.
- End-stage renal disease is five times more common.
- The onset of stroke occurs earlier.
- Hypertension control is lower (Figure 1).

Figure 1. Percent of hypertensive adult population with controlled blood pressure. United States 1988-1994, 1999-2004, 2009-2010.³



Adapted from Lackland 2014.³

While comorbidities such as obesity and diabetes remain as major contributing factors to hypertension and consequences of hypertension in the black community, studies have also described several other associations that require consideration. A relationship between racism (including perceived racism) and hypertension is possible. In addition, the effect of lower socioeconomic status appears to have a larger effect on hypertension prevalence in black men relative to white men. As well, mistrust based on culture is more common in the black community.

Given all of the above information, it is imperative to identify alternative or complimentary approaches to BP management in black individuals with hypertension that are focused on risk identification (including physiologic markers), monitoring, and treatment options that allow for guidance leading to improved treatment outcomes.

The burden of hypertension and downstream consequences in the black population have created an urgent need to identify alternative or complimentary approaches to blood pressure management.

Central Aortic Pressure Measurement and Hypertension

Central aortic BP measurement for identification and monitoring of elevated BP and associated risks is an approach that has been proposed broadly but may be particularly applicable to the black population. The following paragraphs and the subsequent section provide background information regarding non-invasive measurement of central aortic pressures.

Management of hypertension through cuff measurement of peripheral (brachial artery) pressures, which has been in use since the 1800's, has dramatically but incompletely improved the ability of health care providers and their patients to control hypertension and reduce associated end-organ damage. Multiple issues likely contribute to the ongoing socioeconomic burden of hypertension despite the availability of multiple effective medications and widespread educational efforts. Such issues include, but are not limited to, case finding (early diagnosis), continuity and continued follow-up of care, affordability of care, medication adverse effects, medication compliance and challenges in modifying lifestyle behavior.

An underappreciated but clinically relevant area to consider is the precision and reliability of current monitoring, which is based on brachial BP measurements, including patient and health care provider factors. In general, cuff brachial BP might be viewed as a surrogate for central (i.e., aortic) blood pressures; however, differences exist between brachial and aortic BPs and the differences can vary among different individuals.⁵⁻⁷ Aortic pressure represents the actual pressure that is transmitted to organs affected by hypertension (e.g., heart, brain, kidney) due to the closer proximity of the ascending aorta to these vital organs. Non-invasive pulse wave analysis (PWA) is a technique that is based on transformation of peripheral (brachial) arterial pressure waveforms into central aortic pressures waveforms from which the following parameters could be obtained:

- Central aortic systolic and diastolic BPs
- Augmentation index (AIx, a ratio expressing or the reflected pressure wave and pulse pressure in the central aorta). An increase in AIx is indicative of arterial stiffness and vascular aging.
- Central aortic pulse pressure (central systolic minus diastolic BP).
- Pulse pressure amplification (the ratio of peripheral to central pulse pressure)

Peripheral (brachial) BPs highly correlate with central BPs; however, significant variability exists such that central BPs cannot be reliably inferred from brachial pressures. Additionally, brachial systolic BPs are generally higher than central aortic BPs although diastolic BPs are similar. The ability to obtain and quantify these variables provide in-depth understanding of the vascular physiology and help determine risk and potential treatment strategies.

Cuff brachial blood pressure might be viewed as a surrogate for central (i.e., aortic) blood pressures; however, aortic pressure, which differs from brachial pressure, represents the actual pressure that is transmitted to organs affected by hypertension (e.g., heart, brain, kidney) due to the closer proximity of the ascending aorta to these vital organs.

The technology for non-invasive assessment of central aortic pressures through PWA is currently available and approved by the United States Food and Drug Administration (FDA). In recognition of the clinical utility of PWA, a Current Procedural Terminology (CPT) code has been established. The SphygmoCor® XCEL system is a dual arterial pressure monitoring medical device measuring both brachial BPs and central aortic pressures (using partial cuff inflation to record the outgoing brachial waveform), which can be obtained in the clinic at the same time. The SphygmoCor XCEL is the only FDA cleared medical device for non-invasive central arterial pressure waveform measurement and analysis for all adults. The incorporation of PWA in the SphygmoCor System was developed to help guide treatment decisions designed to prevent or reduce long-term target organ damage and cardiovascular events resulting from increased aortic pressure.

The SphygmoCor XCEL system is a dual arterial pressure monitoring medical device for the measurement of brachial and central aortic pressures, which can be obtained in the clinic at the same time.

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Non-Invasive Measurement of Central Aortic BP – Usefulness in Clinical Practice

Multiple studies including several meta-analyses have evaluated central BP variables and indicate that central BP generally has a higher predictive value for cardiovascular events relative to peripheral BP.⁸⁻¹³ It is therefore reasonable to conclude that reductions in hypertension based on central BP will be associated with reduced cardiovascular events and mortality, as has been proven with brachial BP.

Elevated central aortic pressure predicts cardiovascular events and mortality in addition to structural changes (e.g., left ventricular hypertrophy, carotid intima-media thickness and reduced glomerular filtration rate).^{13,14} A recent meta-analysis, which incorporated multiple baseline factors (e.g., risk was increased whether or not brachial BP was elevated), demonstrated that central systolic pressure is independently predictive of cardiovascular events and therefore provides additional risk information.¹⁵

Threshold values for the diagnosis of elevated central arterial pressures have been defined and have been referenced to the threshold values for the diagnosis of hypertension based on brachial pressures and for target goals of treatment.

Incorporation of PWA into the treatment paradigm for hypertension has the following advantages:

1. Confirmation of hypertension so that initiation of medication is more likely to be the correct decision for a patient.
Scenario: Concurrent elevation in brachial and central pressures
2. Avoiding initiation of medication when white coat hypertension is suspected.
Scenario: Elevated brachial pressure and normal central pressures
3. Confirmation that increased treatment may not be needed.
Scenario: Borderline high peripheral pressures and normal central pressures
4. Targeting when to consider reduction of medication.
Scenario: Normal peripheral and low central pressures, or extended period of normal peripheral and normal central pressures (particularly in the setting of medication tolerance issues)

Further details and references supporting the above areas can be found in the Resource section at <https://atcormedical.com/>.

Central Aortic Pressures – Differences in Black Populations

Given the disproportionate impact of hypertension prevalence, morbidity and mortality in the black community as measured, monitored, and treated according to brachial BP, additional paradigms for management are indicated. Non-invasive central aortic BP measurement can provide additional guidance that should be anticipated to contribute to improvement in the current health status of black men and women with hypertension and associated vascular diseases. Published data is briefly highlighted in the following paragraphs.

A critical issue is whether arterial health differs in blacks relative to other racial populations and if physiologic biomarkers can assist in explaining the increased prominence of hypertension (prevalence and outcomes) in blacks. Morris and colleagues¹⁶ hypothesized that racial differences in the prevalence of cardiovascular disease could be attributed, in part, to impaired vascular function in blacks after adjustment for differences in risk factor burden. They assessed vascular function in 385 black and 470 white subjects (mean age 48 years, 45% male). Using digital pulse amplitude tonometry (EndoPAT), reactive hyperemia index (RHI, a measure of microvascular endothelial function) was measured. Arterial wave reflections and arterial stiffness were evaluated based on central Alx and pulse-wave velocity (PWV), respectively, using applanation tonometry (SphygmoCor, Atcor Medical). Compared with whites, blacks had lower RHI (2.1+0.6 vs 2.3+0.6, $p<0.001$), higher Alx (20.8+12.3 vs. 17.5+13.3, $p=0.001$), and higher arterial stiffness, (PWV, 7.4+1.6 vs. 7.1+1.6 m/s, $p=0.001$). After adjustment for cardiovascular disease risk factors, black race remained a significant predictor of lower RH and higher Alx ($p<0.001$ for both) in both men and women and of higher PWV in men ($p=0.01$).

Table 2. Measures of vascular function by racial group adjusted for CVD risk factors.¹⁶

	Baseline PVA	RHI	fRHI	Alx	PWV
Blacks	275+6*	2.1+0.04*	0.8+0.01	21.2+0.6*	7.3+0.1**
Whites	238+6	2.3+0.03	0.8+0.01	16.6+0.6	7.1+0.1

Values are mean + standard error

Values are adjusted for race, sex, age, smoking, history of hypertension or diabetes, BMI, mean arterial pressure, lipids, and glucose. * $p\leq 0.001$. ** $p=0.01$ when compared with whites.

CVD cardiovascular disease; PVA, pulse volume amplitude; RHI, reactive hyperemia index; fRHI, Framingham reactive hyperemia index; Alx, augmentation index; PWV, pulse-wave velocity; BMI, body mass index.

Furthermore, these associations persisted in a subgroup analysis of “healthy” individuals without cardiovascular risk factors.¹⁶ The authors concluded that black race is associated with impaired microvascular vasodilatory function, and greater arterial wave reflections and arterial stiffness. The findings of this study suggest that impairment in these measurements of vascular health may represent the underlying mechanisms for the increased risk in blacks for detrimental long-term vascular outcomes. The additional implication that measurements of arterial health (in addition to simple brachial BP) should be considered in the management of hypertension, particularly in the black population.

Several studies have provided data on vascular changes in black males relative to white males that are consistent with the findings in the previous study. Perhaps more relevant and provocative is the

documentation that changes can be observed at an early age.^{17,18} Heffernan et al performed a cross-sectional study examining whether vascular dysfunction in young black men would contribute to greater central aortic BP compared with young white men.¹⁷ Fifty-five young healthy men (mean age 23 years, 25 blacks and 30 whites) had the following assessments of vascular structure and function: (a) carotid artery intima-media thickness (IMT) and carotid artery-stiffness via ultrasonography, (b) aortic PWV, aortic Alx and wave reflection travel time via radial artery tonometry, and (c) microvascular vasodilatory capacity of forearm resistance arteries with strain-gauge plethysmography. Black men had similar brachial systolic BP (SBP) but greater aortic SBP ($p<0.05$) and carotid SBP ($p<0.05$). Black men also had greater carotid IMT, greater carotid stiffness, greater aortic stiffness and Alx, reduced aortic travel time, and reduced peak hyperemic and total hyperemic forearm blood flow compared with white men ($p<0.05$).

Table 3. Measures of aortic function derived from peripheral pressure waveforms.¹⁷

Variable	White	Black	p-value
Alx (%)	9.0+1.3	0.5+2.4	0.001
Alx75 (%)	15.1+1.6	8.5+2.4	0.022
Augmented pressure (mmHg)	3.1+0.4	1.0+0.9	0.001
Nonaugmented pressure (mmHg)	32+1	34+1	0.203
Reflection time (ms)	176.0+4.5	161.9+3.9	0.025
PWV, m/s	6.0+0.2	7.3+0.3	0.001

Values are means + standard error. Alx, augmentation index; Alx75, Alx normalized to a heart rate of 75 beats/min; PWV, pulse wave velocity.

The authors concluded that young black men have greater central BP, despite comparable brachial BP, relative to young white men.¹⁷ Furthermore, the authors documented that macrovascular and microvascular dysfunction (e.g., carotid artery hypertrophy, increased arterial stiffness, heightened resistance artery constriction/blunted resistance artery dilation, and greater arterial wave reflection) were present at a young age in otherwise healthy black men in which brachial BP appeared unremarkable. While relatively small, the study highlights that central pressure measurements can provide clinically important information to identify black men who are at increased risk of morbidity and mortality from hypertension. The clinical implication is that early intervention may reduce the risk of end-organ damage, morbidity, and mortality.

Young black men have greater central BP, despite comparable brachial BP, relative to young white men. Macrovascular and microvascular dysfunction are present at a young age in otherwise healthy black men in which brachial BP appears unremarkable.¹⁷

While the previous study examined young adults, a study performed in South Africa sought to compare different estimates of arterial stiffness in black and white children.¹⁸ A total of 40 black and 41 white boys (aged 6–8 years) were evaluated with measurements of arterial stiffness (pulse wave velocity (PWV) in different arterial sections, systemic arterial compliance, and carotid stiffness estimates). Arterial stiffness as measured using PWV is generally associated with increased central pressures and augmentation index. Black boys displayed increased PWV (carotid to radial, carotid-to-femoral, and carotid-to-dorsalis pedis), diastolic BP,

and carotid intima-media thickness than white boys ($p < 0.01$ for all values). The authors concluded that black children (6–8 years) have increased arterial stiffness in all sections of the arterial tree, along with higher diastolic BP, and carotid intima-media thickness and “underlines the increasing trend of early-onset vascular aging among black populations.”¹⁸

Schutte et al recently published a review article on ethnicity and arterial stiffness. Arterial stiffness can be considered as a marker of vascular aging.¹⁹ This comprehensive review documented multiple studies that highlighted racial differences that included unfavorable findings in black populations relative to white populations including a larger impact of hypertension on stroke and stroke outcomes, higher measures of arterial stiffness and earlier onset of arterial stiffness. A number of studies have determined that disparities such as increased central BP appear to be independent of peripheral BP and standard cardiovascular risk factors. As previously noted, increased arterial stiffness measures have been documented in young and older black populations relative to similar white populations. The review of publications supported the current state of knowledge in that while genetic factors have yet to be fully evaluated, socioeconomic factors, obesity and diabetes appear to be contributors to racial differences in arterial stiffness. In a separate well-referenced review article of hypertension in the US black population, the authors stated that “Notably, the increased prevalence of both renal failure and LVH in blacks versus whites is present even at comparable levels of brachial BP. Differences in central BP between blacks and whites likely contribute to these findings.”²⁰

“The majority of studies found that populations of African descent present with increased aortic stiffness from young ages onwards when compared to especially white populations.” – Schutte et al. 2020.

Based on the current literature including original research and review publications by international experts, clinical imperatives should be directed to early identification, particularly in the black population, of elevated central pressures as well as PWV, in order to focus resources on preventive interventions.

Conclusion

Hypertension prevalence, morbidity and mortality disproportionately affects the black population. Data indicate differences in arterial health that can be uncovered through non-invasive measurement of central aortic pressures. Early identification of risk and additionally monitoring parameters using PWA is anticipated to positively inform management and improve outcomes. The SphygmoCor dual arterial pressure monitoring device, which can obtain brachial and central aortic BPs (through PWA) at the same time, is a medical tool that should be considered for the management of hypertension.

In conclusion, based on current technology, the availability of a non-invasive dual arterial pressure measurement system, the compelling clinical rationale and the extensive clinical published research, incorporation of central aortic pressure monitoring, which is complementary to continued reliance on brachial pressure monitoring should be considered in the care of black patients with hypertension.

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