Hemodynamic Differences Between Black Patients and White Patients With Essential Hypertension

State of the Art Lecture

Edward D. Frohlich

Physiological studies reported from our laboratory over the past several years have been reviewed and support epidemiological reports indicating that hypertensive cardiac and vascular disease runs a more severe course in the black patient. Although comparison of systemic hemodynamics failed to demonstrate that, for any level of arterial pressure, the magnitude of total peripheral resistance (which is the hemodynamic hallmark of hypertensive disease) differed between black patients and white patients, there are more subtle differences that were ascertained. Thus, although intravascular (plasma) volume contracts as arterial pressure and total peripheral resistance increase in both racial groups, this relation may differ quantitatively. At least in some black patients (43%), intravascular volume may be more expanded; in these patients, this relation is less closely correlated with the renopressor system (i.e., plasma renin activity). Moreover, these studies indicated that, at any level of arterial pressure, cardiac (left ventricular mass and posterior wall thickness) and renal hemodynamic involvement is more severe in the black patient. These findings point to important differences that operate in black patients and white patients with essential hypertension. With further study, these findings may be translated into more specific antihypertensive therapeutic implications for patients of both racial groups with essential hypertension. (Hypertension 1990;15:675—680)

National health statistics and prospective epidemiological studies have reaffirmed conclusions that hypertensive cardiovascular disease is more prevalent in the black population.1-5 Furthermore, strokes and cardiac and renal failure are more common in the black population and probably occur earlier in the natural history of the disease.5-10

Over the past decade, prospective clinical studies have indicated that black patients and white patients with essential hypertension may differ in their responses to different forms of antihypertensive monotherapy.11-13 This difference in response suggests that the pressor mechanisms involved in the pathophysiology, and possibly the pathogenesis, of the disease may vary between the two populations. During these years we have reported, in a series of studies concerning certain hemodynamic characteristics of patients with hypertension, evidence that tends to support the foregoing concepts that the underlying pathophysiological mechanisms may differ, at least in part, between the two groups.

This paper summarizes our findings that 1) participation of certain pressor mechanisms seems to differ quantitatively between black patients and white patients, 2) vascular disease (at least in some circulations) may be more severe in the black population, and 3) the black patient with essential hypertension exhibits greater cardiac involvement in hypertension, which is demonstrated by a closer relation between single temporal pressure and hemodynamic assessments and left ventricular mass and hypertrophy.

Hemodynamic Assessment and Findings

All patients reported in this communication were subjects of four studies that have been reported earlier,14-17 and the methods used to evaluate the hemodynamic indexes are detailed therein and elsewhere.14-25

Normotensive individuals were defined as having repeated (on at least three separate occasions) systolic and diastolic arterial pressure measurements consistently less than 140 mm Hg and less than 90 mm Hg, respectively. Patients with borderline hypertension had diastolic pressure measurements that were 90 mm Hg (or higher) on several occasions, but at times their diastolic pressures were found to be

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less than 90 mm Hg. Patients with essential hypertension had no demonstrable cause elucidated for their persistently elevated (i.e., >90 mm Hg) diastolic arterial pressure on a comprehensive medical evaluation.

**Systemic Hemodynamics**

This study reported hemodynamic findings from 126 white and black patients, 51 with borderline hypertension and 75 with established essential hypertension; they were compared with findings from 29 age-matched normotensive volunteer subjects (Table 1).15 The age, race, and gender of these black patients and white patients were matched, and their arterial pressure levels were also matched in order to determine whether, at any level of pressure, total peripheral resistance was different between the racial groups. Heart rate was significantly faster in all patients with hypertension than in normotensive subjects; heart rate was faster in the white patients with hypertension than in the black patients (p<0.05). At any level of arterial pressure, there was no difference between the two racial groups with respect to cardiac output and total peripheral resistance. However, it was of interest that, in both racial groups of patients, intravascular (and plasma) volume was inversely related to total peripheral resistance (for all patients, r = −0.34, p < 0.001; for white patients, r = −0.25, p < 0.05; and for black patients, r = −0.48, p < 0.01).

**Intravascular Volume and Plasma Renin Activity**

In another 152 male patients with uncomplicated essential hypertension who were studied consecutively for the interrelations among arterial pressure, plasma volume, and plasma renin activity, 130 patients (35 black and 95 white) were classified as having either an expanded or a contracted plasma volume.14 Normal plasma volume in normotensive male volunteer subjects was 18.0 ± 1.0 ml/cm body height. For the purposes of that study,14 plasma volume exceeding 19.0 ml/cm was considered arbitrarily to be “expanded” plasma volume, and any level of plasma volume less than 17.0 ml/cm was considered arbitrarily to be “contracted” plasma volume. There were 22 patients (17 white and 5 black) whose plasma volume was found to be normal (i.e., 18.0 ± 0.9 ml/cm), and because of the small number in this group, they were excluded from the analysis. Of the remaining 130 patients (35 black and 95 white), 43% of the black patients and 21% of the white patients were thus “volume contracted” (p<0.05). In the white patients with contracted plasma volume, arterial pressure and plasma renin activity were significantly higher (p<0.05 and p<0.001, respectively) than in the white patients with expanded plasma volume. In contrast, there was no significant difference between the levels of arterial pressure and plasma renin activity in the volume-expanded and volume-contracted black patients. Nevertheless, more black patients than white patients had low plasma renin activity, and these black patients did not manifest the inverse relation between plasma renin activity and plasma volume that was demonstrated in white patients. Hence, there is a segment of black patients with essential hypertension in whom arterial pressure, intravascular volume, and plasma renin activity do not demonstrate the normal interrelations among these three variables that were found in white patients, and these black patients seemed to be more volume dependent for any level of arterial pressure (Table 2).14

**Regional Hemodynamics**

In this study, 60 white and black patients with essential hypertension (15 men and 15 women in
TABLE 2. Comparison of Intravascular Volume and Related Indexes in White and Black Male Patients With Essential Hypertension

<table>
<thead>
<tr>
<th>Indexes</th>
<th>Volume “expanded”</th>
<th>Volume “contracted”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black</td>
<td>White</td>
</tr>
<tr>
<td>Patient (n)</td>
<td>15 (43%)</td>
<td>20 (21%)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>50±2</td>
<td>47±3</td>
</tr>
<tr>
<td>Arterial pressure (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>172±7</td>
<td>159±3*</td>
</tr>
<tr>
<td>Diastolic</td>
<td>113±4</td>
<td>97±4t</td>
</tr>
<tr>
<td>Serum creatinine (mg/dl)</td>
<td>1.2±0.1</td>
<td>1.2±0.1</td>
</tr>
<tr>
<td>Creatinine clear (ml/min)</td>
<td>95±8</td>
<td>102±4</td>
</tr>
<tr>
<td>Plasma volume (ml/cm)</td>
<td>200±0.4</td>
<td>210±0.6</td>
</tr>
<tr>
<td>PRA (ng/ml/hr)</td>
<td>0.7±0.2</td>
<td>0.9±0.2</td>
</tr>
</tbody>
</table>

Values are mean±1 SEM. Table is adapted from Reference 14. PRA, plasma renin activity.

*p<0.05 vs. black patients.
†p<0.025 vs. black patients.
‡p<0.005 vs. black patients.

Each racial group) were compared hemodynamically.16 The black patients and white patients were matched for levels of mean arterial pressure, age, and gender. Once again, the systemic hemodynamic data demonstrated that at any level of arterial pressure, cardiac index and total peripheral resistance were similar in the two racial groups. Furthermore, there were no differences between groups with respect to the hemodynamic characteristics of the splanchnic circulation. However, at any level of mean arterial pressure or total peripheral resistance, renal blood flow was significantly less (p<0.003) and renal vascular resistance was significantly greater (p<0.002) in the black patients (Table 3).16 These renal hemodynamic differences appeared to be more pronounced in the male black patients. However, when all of the patients were analyzed as a single group, only the black patients showed a significantly different correlation between the levels of mean arterial pressure and renal vascular resistance (p<0.05) (Figure 1).

Cardiac Structure

In a fourth study, which involved 30 black and 30 white patients with established essential hypertension who were similarly matched for age, gender, and level of mean arterial pressure, systemic hemodynamic findings were similar. Left ventricular wall thickness measurements were also similar, but the left ventricular mass index was significantly greater in

TABLE 3. Systemic and Regional Hemodynamic Characteristics of White and Black Patients With Essential Hypertension

<table>
<thead>
<tr>
<th>Indexes</th>
<th>White patients</th>
<th>Black patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>46±2.5</td>
<td>46±4.0</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.94±0.04</td>
<td>1.77±0.05</td>
</tr>
<tr>
<td>Arterial pressure (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>161±4</td>
<td>164±4</td>
</tr>
<tr>
<td>Diastolic</td>
<td>95±3</td>
<td>91±2</td>
</tr>
<tr>
<td>Mean</td>
<td>110±3</td>
<td>113±2</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>73±3</td>
<td>70±2</td>
</tr>
<tr>
<td>Cardiac index (l/min/m²)</td>
<td>3.1±0.1</td>
<td>3.0±0.1</td>
</tr>
<tr>
<td>TPR (units/m²)</td>
<td>36±2</td>
<td>30±2</td>
</tr>
<tr>
<td>Plasma volume (ml)</td>
<td>2,869±163</td>
<td>2,708±136</td>
</tr>
<tr>
<td>Splanchnic circulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood flow (ml/min)</td>
<td>821±124</td>
<td>647±74</td>
</tr>
<tr>
<td>Vascular resistance (units)</td>
<td>1.78±0.29</td>
<td>1.99±0.26</td>
</tr>
<tr>
<td>Renal circulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood flow (ml/min)</td>
<td>1,115±56</td>
<td>947±75</td>
</tr>
<tr>
<td>Vascular resistance (units)</td>
<td>1.07±0.05</td>
<td>1.30±0.12</td>
</tr>
</tbody>
</table>

Values are mean±1 SEM. Table is adapted from Reference 16. TPR, total peripheral resistance.

*Covariate analysis revealed significantly lower renal blood flow (p<0.003) and higher renal vascular resistance (p<0.002) in black patients.
the black patients (147±8 vs. 122±8; p<0.05). Of particular pertinence was the finding that the left ventricular posterior wall thickness was directly related to the height of systolic (r=0.45, p<0.008) and diastolic (r=0.44, p<0.004) pressure and to the total peripheral resistance (r=0.32, p<0.046).

Comments

The results of this series of studies confirm the epidemiological findings that the course of hypertensive cardiovascular disease is more severe in black patients with essential hypertension. However, there are certain subtleties in these physiological studies that bear emphasis. For example, total peripheral resistance, the hemodynamic hallmark of hypertensive disease, was the same in black patients and white patients at equivalent levels of arterial pressure. However, these studies did show that, when arterial pressure levels were matched between black patients and white patients with essential hypertension, cardiac mass and left ventricular wall thickness correlated significantly with the height of arterial pressure and total peripheral resistance in the black (but not the white) patients. These findings may be answered with more careful studies comparing the integrated 24-hour pressures of the two racial groups and the other hemodynamic and nonhemodynamic factors that relate to the development of left ventricular hypertrophy. This relation also pertains with respect to the renal circulation. Thus, two major target organs of hypertension, the heart and kidney, seem to sustain a more severe hemodynamic insult in black patients who were matched with white patients with respect to age, gender, and level of arterial pressure.

Of intriguing interest were the differences between the two racial groups with respect to two mechanisms that participate actively in control of arterial pressure: intravascular volume and the renopressor system (i.e., plasma renin activity). Earlier studies from our laboratory demonstrated that, in patients with essential hypertension, the higher the level of diastolic arterial pressure or total peripheral resistance, the more contracted is the circulating intravascular (plasma) volume. To be sure, some patients with hypertension do not demonstrate this inverse relation, and these patients with more volume-dependent hypertension have parenchymal disease of the kidney, steroid-dependent hypertension, or so-called volume-dependent essential hypertension. In these latter patients, plasma renin activity is lower. Plasma renin activity normally is suppressed in proportion to the expansion of intravascular volume; thus, in black patients with hypertension, the lower plasma renin activity may be explainable, in part, on the basis of the greater

![Figure 1: Graph showing relation between height of arterial pressure and renal vascular resistance in 60 male and female patients with essential hypertension. Figure is adapted with permission.](image1)

![Figure 2: Graph showing relation between total blood volume and total peripheral resistance (TPR) in 126 white and black patients with essential hypertension. Same inverse correlation exists in two racial groups. Figure is adapted with permission.](image2)
degree of expansion of intravascular (i.e., plasma) volume.

However, this relation is not solely based on the interaction between intravascular volume and plasma renin activity for several reasons. First, not all black patients with essential hypertension have an expanded intravascular volume; 57% (a majority of black patients) demonstrated a contracted volume. Second, the negative relation between intravascular volume and total peripheral resistance (and arterial pressure) was demonstrable in both the black patient and the white patient with essential hypertension (Figure 2). These points are particularly relevant in order to point out the invalid conclusions that have been derived from our studies that demonstrated the black patient to be more volume dependent. This is simply not the case (although in some black patients with contracted plasma volume, that volume is greater than in volume-contracted hypertensive white patients).

This erroneous physiological conclusion has been further perpetuated by generalizations and inferences from reports comparing therapeutic responses of black patients and white patients with essential hypertension. Thus, in the Veterans Administration Cooperative Study, black patients (as a group) responded better to diuretics than to β-adrenergic receptor blocking drugs; white patients with essential hypertension (as a group) responded better to β-adrenergic receptor blocking drugs than to diuretics. However, when both drugs were administered simultaneously to black patients and white patients, the response of arterial pressure of the two racial groups was similar. It should be emphasized that many black patients in this study responded well to the β-blocker therapy and that, conversely, many white patients responded well to diuretic monotherapy. A second invalid extrapolation has been made with respect to the use of calcium antagonist therapy in black patients. For example, in one study, black patients (as a group) responded better than white patients to verapamil monotherapy. Nevertheless, there were white patients who responded well to verapamil, and in a number of other studies involving calcium antagonists, white patients responded well to monotherapy just as some black patients may not have responded as well to this form of treatment.

Thus, present findings support the conclusions that there are important physiological and pathophysiological differences that are identified between black patients and white patients with essential hypertension. These data lend support to the epidemiological findings that hypertensive cardiac and vascular disease may run a more severe course in the black patient. There is other evidence to indicate that the pressor mechanisms that subserve hypertensive disease, in part, reflect a difference between the racial groups in the relations between intravascular volume and regulation of the renopressor system and their respective controls on arterial pressure. Clearly, as we learn more of the regulation of these pressure control systems in black patients and white patients, there is no doubt that more insight will be derived to permit more precise control of the abnormally elevated arterial pressure in these patients.

Conclusions

A series of recent studies from this laboratory have provided important physiological evidence to indicate that differences exist between black patients and white patients with essential hypertension. Thus, when age, gender, and height of arterial pressure are matched in black patients and white patients with essential hypertension, systemic hemodynamics are generally similar although heart rate seems to be faster in white patients. However, for any level of arterial pressure (or total peripheral resistance), there is greater impairment of intrarenal hemodynamics and of the heart in the black patients. Moreover, the regulation of intravascular volume as a function of hemodynamics differs quantitatively in black patients (as a group). Thus, although plasma volume contracts in both racial groups as arterial pressure and total peripheral resistance increase, this volume contraction may not be as prominent in black patients, and this relation is not as close in black patients with essential hypertension (at least in some). These findings have therapeutic implications that should be explored more closely by taking these subtle differences into consideration.

References


29. Massie BM: Demographic considerations in the selection of antihypertensive therapy. Am J Cardiol 1987;60(suppl I): 121–126


KEY WORDS • plasma renin activity • antihypertensive therapy • splanchnic circulation • left ventricular hypertrophy • plasma volume • hemodynamics • renal circulation
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