Differential Control of Systolic and Diastolic Blood Pressure
Factors Associated With Lack of Blood Pressure Control
in the Community

Donald M. Lloyd-Jones, Jane C. Evans, Martin G. Larson, Christopher J. O’Donnell,
Edward J. Roccella, Daniel Levy

Abstract—Data from the Third National Health and Nutrition Examination Survey, phase 2 (1991 to 1994), indicate that among hypertensive individuals in the United States, 53.6% are treated and only 27.4% are controlled to goal levels. We sought to determine whether poor hypertension control is due to lack of systolic or diastolic blood pressure control, or both. We studied Framingham Heart Study participants examined between 1990 and 1995 and determined rates of control to systolic goal (<140 mm Hg), diastolic goal (<90 mm Hg), or both (systolic <140 and diastolic <90 mm Hg). Of 1959 hypertensive subjects (mean age 66 years, 54% women), 32.7% were controlled to systolic goal, 82.9% were controlled to diastolic goal, and only 29.0% were controlled to both. Among the 1189 subjects who were receiving antihypertensive therapy (60.7% of all hypertensive subjects), 49.0% were controlled to systolic goal, 89.7% were controlled to diastolic goal, and only 47.8% were controlled to both. Thus, poor systolic blood pressure control was overwhelmingly responsible for poor rates of overall control to goal. Covariates associated with lack of systolic control in treated subjects included older age (OR for age 61 to 75 years, 2.43, 95% CI 1.79 to 3.29; OR for age >75 years, 4.34, 95% CI 3.10 to 6.09), left ventricular hypertrophy (OR 1.63, 95% CI 1.04 to 2.54), and obesity (OR for body mass index ≥30 versus <25 kg/m², 1.49, 95% CI 1.08 to 2.06). In this community-based sample of middle-aged and older subjects, overall rates of hypertension control were remarkably similar to those in the Third National Health and Nutrition Examination Survey. Poor blood pressure control was overwhelmingly due to lack of systolic control, even among treated subjects. Therefore, clinicians and policymakers should place greater emphasis on the achievement of goal systolic levels in all hypertensive patients, especially those who are older or obese or have target organ damage. (Hypertension. 2000;36:594-599.)

Key Words: hypertension detection and control ■ blood pressure ■ epidemiology ■ antihypertensive therapy

Hypertension is a major risk factor for the development of stroke, congestive heart failure, coronary heart disease, peripheral vascular disease, and renal failure. Despite advances in understanding of the pathophysiology of hypertension and advances in antihypertensive therapy during the past 3 decades, the public health burden of hypertension remains substantial, with nearly 50 million hypertensive individuals in the United States.1 In recent years, gains in hypertension awareness, treatment, and control in the population have leveled off or reversed. Data from the Third National Health and Nutrition Examination Survey (NHANES III, phase 2, performed in 1991 to 1994) indicate that only 53.6% of hypertensives were treated and only 27.4% were controlled to goal levels of <140 mm Hg systolic and <90 mm Hg diastolic.2 It is unclear whether poor rates of hypertension control are due to lack of systolic blood pressure (SBP) control, lack of diastolic blood pressure (DBP) control, or both. Until recently, greater clinical emphasis was placed on the control of elevated DBP. With accumulating epidemiological and clinical trial data, however, the Fifth and Sixth Reports of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-V and JNC-VI) have placed equal emphasis on control of both SBP and DBP. We sought to determine rates of antihypertensive treatment among subjects with hypertension in a community-based sample that was contemporaneous with NHANES III, phase 2. We also sought to determine rates of blood pressure control to SBP goal, DBP goal, and to both and to identify covariates associated with lack of blood pressure control among treated subjects.
Methods

Study Sample
The Framingham Heart Study is an ongoing prospective epidemiological cohort study designed to evaluate potential risk factors for coronary heart disease. Study design and entry criteria for participating subjects have been detailed elsewhere. All examinations and procedures were approved by the Institutional Review Board of Boston University School of Medicine.

Of 4962 subjects examined between 1990 and 1995, we included only those with hypertension, defined as an SBP of $\geq 140$ mm Hg or a DBP of $\geq 90$ mm Hg, or those who were receiving antihypertensive therapy at the time of the examination. Our definition of hypertension coincides with the definitions used in NHANES III, JNC-V, and JNC-VI.

There were 2106 subjects with hypertension; 263 had incomplete data for covariates of interest (prevalent cardiovascular disease, ECG evidence of left ventricular hypertrophy, current smoking, diabetes, total cholesterol and HDL cholesterol levels, and body mass index [BMI]) from their examination during the study period. BMI measures from the immediate prior examination were used to fill in missing data if measured within 2 years. Missing measures of more static covariates (eg, total cholesterol level) were used from prior examinations if measured within the previous 4 years. After we attempted to fill in as many missing covariates as possible, a total of 147 subjects were excluded, leaving 1959 hypertensive subjects for analysis.

Blood Pressure Measurement
At each examination, blood pressure was measured twice in the left arm by an examining physician using a mercury column sphygmomanometer after the subject had been at rest in the seated position for $\geq 5$ minutes. SBP level was defined as the first appearance of sound (Korotkoff phase 1), and DBP level was defined as the disappearance of sound (phase 5). Measurements were separated by $\geq 2$ minutes. The mean values of the 2 separate systolic and 2 separate diastolic blood pressure measurements were used to derive the reported blood pressure for that examination.

Hypertension Control
SBP control was defined as an SBP of $<140$ mm Hg at the time of the Framingham Heart Study examination. DBP control was defined as a DBP of $<90$ mm Hg. Overall control to goal blood pressure levels was defined as an SBP of $<140$ mm Hg and a DBP of $<90$ mm Hg.

Statistical Analysis
All analyses were performed with SAS statistical software (SAS Institute). A 2-tailed probability value of $<0.05$ was considered to be statistically significant. We first determined the rates of antihypertensive treatment and control among all 1959 subjects with hypertension. The proportion of subjects controlled to SBP goal, DBP goal, and both were calculated separately. With logistic regression analysis, the OR and 95% CI for antihypertensive treatment were determined for subjects according to age group, sex, prevalent cardiovascular disease (defined as history of myocardial infarction, stroke, transient ischemic attack, congestive heart failure, or intermittent claudication), ECG evidence of left ventricular hypertrophy, current smoking, diabetes, and categories of total cholesterol, HDL cholesterol, and BMI. Stepwise logistic regression was used to select covariates significantly associated with treatment after forcing age group into the model, because age was the most significant covariate associated with antihypertensive treatment.

We then determined rates of control to SBP goal, DBP goal, and both among the 1189 treated hypertensive subjects. Logistic regression was performed to determine the covariates associated with lack of SBP control and with lack of DBP control in this subgroup. Stepwise logistic regression was performed, as described, to determine significant predictors of lack of control, and the final models were analyzed with the covariates selected with the stepwise models. Because there were very few subjects ($n=14$) who were controlled to SBP goal but not DBP goal, the models for lack of control to SBP goal and lack of overall control were nearly identical. Therefore, we have presented only the models for lack of control to SBP goal and DBP goal.

Results

Study Sample
There were 1959 hypertensive subjects in the study sample. The mean age was 66 years, and 54% were women. Characteristics of the study sample are shown in Table 1.

All Hypertensive Subjects
Among the 1959 subjects with hypertension, 1189 (60.7%) were receiving antihypertensive therapy, which is slightly higher than the treatment prevalence of 53.6% observed in the concurrent NHANES III, phase 2 national sample. The blood pressure distribution of all hypertensive subjects is shown in Figure 1. In this group, 32.7% were controlled to SBP goal ($<140$ mm Hg), 82.9% were controlled to DBP goal ($<90$ mm Hg), and only 29.0% were controlled to both. The percentage of 29.0% controlled to overall goal that we observed is similar to the percentage of 27.4% observed in the concurrent NHANES sample.

In the multivariate model, covariates that were associated with antihypertensive treatment included older age, ECG evidence of left ventricular hypertrophy, and obesity. Subjects aged 61 to 75 years had an OR for treatment of 2.29 (95% CI 1.84 to 2.84), and subjects aged $>75$ years had an OR of 2.72 (2.11 to 3.51), compared with subjects $\leq 60$ years of age. Subjects with left ventricular hypertrophy had an OR for treatment of 1.78 (1.17 to 2.70) compared with those without hypertrophy. Subjects with a BMI of 25 to 29.9 kg/m² had an OR of 1.26 (1.00 to 1.60), whereas those with a BMI of $\geq 30$ kg/m² had an OR of 1.55 (1.21 to 2.00) compared with those with a BMI of $<25$ kg/m².

Control Among Treated Hypertensive Subjects
Figure 2 shows the distribution of SBP and DBP among the 1189 treated hypertensive subjects. In this group, 49.0% were controlled to SBP goal, 89.7% were controlled to DBP goal, and 47.8% were controlled to both. Thus, poor systolic control was overwhelmingly responsible for poor rates of overall control to goal.

Covariates Associated With Lack of Hypertension Control
We first examined the univariate relationships for gender and age with hypertension control. In these analyses, gender and age were each associated with rates of control to goal SBP and DBP levels among treated subjects with hypertension. As shown in Figure 3, women had lower rates of SBP control and overall control, whereas they had higher rates of DBP control compared with men. Similarly, Figure 4 demonstrates that older subjects had lower rates of SBP control and overall control but higher rates of DBP control. These age trends were observed in both men and women (data not shown).

With stepwise logistic regression, the covariates that were associated with lack of SBP control were older age, left ventricular hypertrophy, and higher BMI. Covariates associ-
ated with lack of DBP control are also shown in Table 2. These covariates were entered into the final multivariate models for SBP and DBP control. Increasing age was significantly associated with lack of SBP control, as were left ventricular hypertrophy and a BMI of $30 \text{ kg/m}^2$.

Discussion

The rates of hypertension treatment and control that we observed in our community-based sample were similar to those observed during the same time period in NHANES III, phase 2. Among our subjects with hypertension, 60.7% were receiving treatment, and only 29.0% were controlled to goal levels of $140/90 \text{ mm Hg}$. Blood pressure control was poor even among treated patients, at 47.8%, and this was overwhelmingly due to the lack of SBP control.

Our findings extend the observations of low rates of hypertension control in the NHANES III, phase 2 sample and in other samples from community surveillance and managed-care settings by focusing on the differential attainment of SBP and DBP goals and by highlighting factors associated with lack of control. Interestingly, the same covariates that were associated with antihypertensive treatment and control were also associated with lack of DBP control.

Table 1. Baseline Characteristics of All 1959 Hypertensive Subjects and the Subset of 1189 Treated Hypertensive Subjects Examined Between 1990 and 1995 in the Framingham Heart Study

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Subjects, n (%)</th>
<th>Treated Subjects, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men (n=904)</td>
<td>Women (n=1055)</td>
</tr>
<tr>
<td></td>
<td>Men (n=532)</td>
<td>Women (n=657)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤60</td>
<td>336 (37.2)</td>
<td>295 (28.0)</td>
</tr>
<tr>
<td>61–75</td>
<td>385 (42.6)</td>
<td>423 (40.1)</td>
</tr>
<tr>
<td>&gt;75</td>
<td>183 (20.2)</td>
<td>337 (31.9)</td>
</tr>
<tr>
<td>Prevalent CVD</td>
<td>130 (14.4)</td>
<td>143 (13.6)</td>
</tr>
<tr>
<td>ECG evidence of LVH</td>
<td>75 (8.3)</td>
<td>575 (5.4)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>118 (13.1)</td>
<td>133 (12.6)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>72 (8.0)</td>
<td>74 (7.0)</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤5.2</td>
<td>460 (50.9)</td>
<td>347 (32.9)</td>
</tr>
<tr>
<td>5.2–6.2</td>
<td>347 (38.4)</td>
<td>446 (42.3)</td>
</tr>
<tr>
<td>&gt;6.2</td>
<td>97 (10.7)</td>
<td>262 (24.8)</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤1.2</td>
<td>306 (33.8)</td>
<td>706 (66.9)</td>
</tr>
<tr>
<td>0.9–1.2</td>
<td>337 (37.3)</td>
<td>252 (23.9)</td>
</tr>
<tr>
<td>&lt;0.9</td>
<td>261 (28.9)</td>
<td>97 (9.2)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤25</td>
<td>177 (19.6)</td>
<td>304 (28.8)</td>
</tr>
<tr>
<td>25–25.9</td>
<td>424 (46.9)</td>
<td>402 (38.1)</td>
</tr>
<tr>
<td>≥30</td>
<td>303 (33.5)</td>
<td>349 (33.1)</td>
</tr>
</tbody>
</table>

CVD indicates cardiovascular disease; LVH, left ventricular hypertrophy.

Figure 1. SBP and DBP levels of all 1959 subjects with hypertension. The vertical line represents the cut point for control to SBP goal ($140 \text{ mm Hg}$); the horizontal line represents the cut point for control to DBP goal ($90 \text{ mm Hg}$). Percentages in the margin indicate the proportion of subjects falling above and below the cut point. Percentages within the graph indicate the proportion of subjects in a given quadrant.

Figure 2. SBP and DBP levels of 1189 treated subjects with hypertension. Explanations are as in Figure 1.
that elevated SBP is far more common than elevated DBP.

However, epidemiological and actuarial data suggest that greater clinical and public health efforts should be directed at achieving goal SBP levels in all hypertensive patients, especially those who are older, are overweight, or have target organ damage such as left ventricular hypertrophy.

**Figure 3. Control to SBP goal, DBP goal, or both by gender among 1189 treated subjects with hypertension. Open columns represent men (n=532); filled columns represent women (n=657).**

**Historical Perspective on Blood Pressure Control**

Historically, elevated DBP was thought to confer a greater risk for cardiovascular events than elevated SBP, which was thought to be part of the “normative” aging process. In addition, early clinical trials of blood pressure lowering used DBP to define hypertension. Thus, the earliest evidence of the benefit of lowering blood pressure related to lowering of DBP.

Treatment recommendations in the first 4 JNC reports, published between 1977 and 1988, placed greater emphasis on the treatment and control of diastolic hypertension. However, epidemiological and actuarial data suggest that elevated SBP is far more common than elevated DBP and that elevated SBP is at least as strong a risk factor as elevated DBP for the development of cardiovascular disease. Clinical trial data have also now demonstrated impressive reductions in cardiovascular events with the treatment of systolic hypertension in older patients. Therefore, the more recent JNC-V and JNC-VI reports, as well as the World Health Organization/International Society of Hypertension guidelines, have advocated the importance of control of both SBP and DBP.

Clinicians appear more likely at office visits to increase antihypertensive medications for DBP elevation than for SBP elevation. In a population of hypertensive veterans, Berlowitz et al reported that increases in drug therapy were most common (35.0% of visits) when the patient had a DBP of ≥90 mm Hg and medications had been increased at the previous visit, whereas increases were less common when the patient had an SBP of ≥165 mm Hg and a DBP of <90 mm Hg (21.6% of visits).

Clinicians appear to be especially reluctant to treat older patients to blood pressure goals, perhaps because of perceived lower benefits of treatment among the elderly and concerns about greater risk of side effects. Yet, it is precisely the older patients who are at the highest absolute risk for developing the sequelae of uncontrolled hypertension and in whom treatment has been shown to reduce risk. The historical preoccupation with DBP may have created the misperception that the treatment of hypertension requires only control of the diastolic component. Consequently, older patients with an elevated SBP, in whom the DBP often is normal, may be undertreated because they are perceived to be “controlled.” If this is the case, greater emphasis in national guidelines should be placed on the prevalence of elevated SBP, the risks associated with it, and the benefits of controlling it. Furthermore, revision of the criteria used by the Food and Drug Administration to approve antihypertensive medications, which are currently based only on DBP lowering, may be warranted.

In recent years, several investigators have suggested that increased pulse pressure (defined as SBP minus DBP), rather than or in addition to elevated SBP or elevated DBP, confers the greatest risk of adverse sequelae associated with hypertension. No data are available from clinical trials that have examined strategies of lowering pulse pressure. If indeed increased pulse pressure does confer risk and the control of pulse pressure decreases risk, then more aggressive efforts at preferential control of SBP should lead to decreased pulse pressure and fewer events.

**Potential Limitations**

Our study sample was composed of middle-aged and older white individuals. SBP tends to rise linearly with advancing age, whereas DBP rises until the sixth decade, after which it tends to fall. Therefore, a younger, ethnically diverse sample might include more subjects with diastolic hypertension who are more prone to poor DBP control. However, the vast majority of hypertensive individuals are middle aged or older, so the findings of our study likely pertain to most hypertensive populations. Given the degree of scrutiny to which Framingham Heart Study participants...
have been subjected, one might expect community physicians in Framingham to treat hypertension more aggressively than physicians in other communities. However, the rates of control to goal blood pressure were remarkably similar between our sample and NHANES III, which was drawn from a representative national sample. Finally, our findings are based on 2 blood pressure readings obtained at a single examination. It is therefore possible that some subjects were misclassified with regard to hypertension status or control.

Conclusions
In the present sample of middle-aged and older subjects, overall rates of hypertension control were remarkably similar to those in NHANES III. Poor control was overwhelmingly due to lack of SBP control, even among treated subjects. Therefore, clinicians and policymakers should place greater emphasis on achieving goal SBP levels in all hypertensive patients, especially those who are older or obese or have target organ damage.

References

TABLE 2. Covariates Associated With Lack of Control to SBP Goal (<140 mm Hg) or DBP goal (<90 mm Hg) Among 1189 Treated Hypertensive Subjects

<table>
<thead>
<tr>
<th>Covariate</th>
<th>OR for Lack of Control to Goal Level (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI, kg/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 25</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>25–29.9</td>
<td>1.07 (0.79, 1.45)</td>
<td>0.022</td>
</tr>
<tr>
<td>≥ 30</td>
<td>1.49 (1.08, 2.06)</td>
<td>0.005</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1.2</td>
<td>1.0 (reference)</td>
<td></td>
</tr>
<tr>
<td>0.9–1.2</td>
<td>0.73 (0.47, 1.15)</td>
<td>0.036</td>
</tr>
<tr>
<td>&lt; 0.9</td>
<td>0.49 (0.28, 0.85)</td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>1.75 (1.16, 2.63)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

CVD indicates cardiovascular disease; LVH, left ventricular hypertrophy.


Differential Control of Systolic and Diastolic Blood Pressure: Factors Associated With Lack of Blood Pressure Control in the Community
Donald M. Lloyd-Jones, Jane C. Evans, Martin G. Larson, Christopher J. O'Donnell, Edward J. Roccella and Daniel Levy

Hypertension. 2000;36:594-599
doi: 10.1161/01.HYP.36.4.594

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://hyper.ahajournals.org/content/36/4/594

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Hypertension can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Hypertension is online at:
http://hyper.ahajournals.org//subscriptions/