# Screening for High Blood Pressure: A Review of the Evidence for the U.S. Preventive Services Task Force

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In the United States, hypertension is responsible for 35% of all cardiovascular events (myocardial infarction and stroke), 49% of all episodes of heart failure, and 24% of all premature deaths (1). Patients with hypertension have 2 to 4 times more risk for stroke, myocardial infarction, heart failure, and peripheral vascular disease than patients without hypertension (2). Additionally, they have an increased risk for end-stage renal disease, retinopathy, and aortic aneurysm (1,3,4). This substantial burden of suffering from hypertension, in combination with a feasible and accurate means of detection and a clear benefit from treatment (5), have led to a widespread recommendation for screening for hypertension.

In 1996, the U.S. Preventive Services Task Force (USPSTF) reviewed the evidence regarding screening for hypertension (5). Based on its review, the USPSTF strongly recommended screening adults 21 and older using standard office sphygmomanometry. Although they did not recommend a specific interval for screening, they noted that measurement every 2 years for patients with previously normal blood pressures and every year in persons with borderline levels may be prudent.

In this report, we systematically examine newer evidence relevant to screening for hypertension in adults to assist the U.S. Preventive Services Task Force in updating its recommendations and the *Guide to Clinical Preventive Services* (5).

## Methods

### Analytic Framework and Key Questions

To examine the role of outpatient clinical screening for hypertension in adults, we first developed an analytic framework depicting key questions of interest to the USPSTF (Figure 1).

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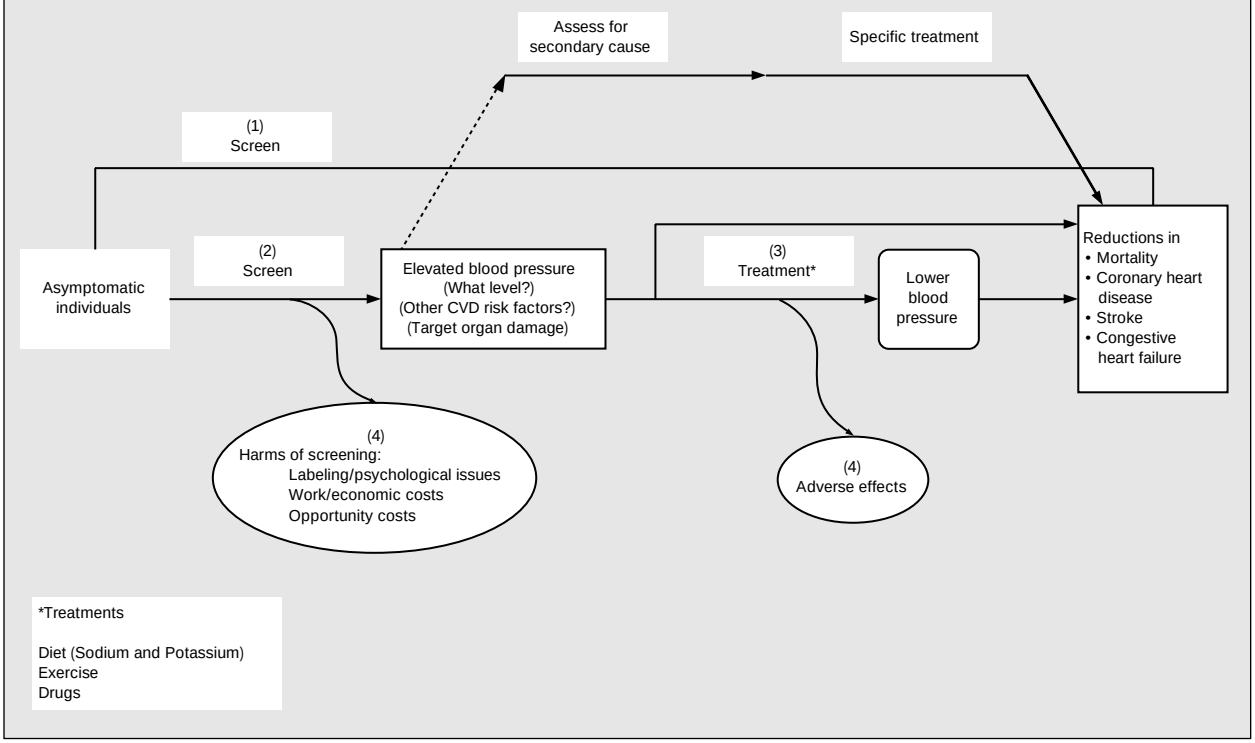
Reprints of the USPSTF recommendation based on this evidence review can be found in "Screening for High Blood Pressure: Recommendations and Rationale," available on the AHRQ Web site and in the *Guide to Clinical Preventive Services, Third Edition: Periodic Updates.* This chapter first appeared as an article in *Am J Prev Med*. 2003;25(2):151–158.

**Figure 1. Analytic framework**




The arrows in the analytic framework represent steps in the chain of logic connecting screening with defined outcomes: cardiovascular disease (CVD) and reduction of mortality.

Four key questions guided our literature searches and synthesis of the evidence:

- **Key Question No. 1:** Does screening and early treatment of hypertension reduce cardiovascular disease and mortality compared with usual care?
- **Key Question No. 2:** How can we most effectively identify patients with hypertension for whom treatment will be beneficial?
- **Key Question No. 3:** How effective is the treatment of hypertension (pharmacological or nonpharmacological) in reducing cardiovascular disease events and mortality?
- **Key Question No. 4:** What are the adverse effects of screening and treatment for hypertension?

We used the 1996 *Guide to Clinical Preventive Services* (5) and searches of MEDLINE, DARE, or the COCHRANE Collaboration Library for systematic reviews published since 1995 and focused searches of MEDLINE to identify new evidence on the benefits of detecting and treating hypertension. When a good quality, recent systematic review was available, we used it to summarize previous research and searched MEDLINE only for more recent articles. When such a review was not available, we identified English-language articles from comprehensive searches of the MEDLINE database between January 1966 and January 2002 and used manual searches of relevant articles and personal libraries, as well as peer review, to ensure that we included all appropriate articles.

## Inclusion Criteria for Admissible Evidence

We included recent systematic reviews and individual observational studies or randomized controlled trials (RCTs) that examined the following

topics: the epidemiology of hypertension; the accuracy and reliability of screening; the benefits of pharmacologic and nonpharmacological treatment of elevated blood pressure; and the adverse effects of screening or treatment for hypertension.

## Data Extraction and Synthesis

Two authors reviewed abstracts of potentially relevant articles to determine whether they should be included. When the reviewers disagreed, we obtained the full articles and resolved the disagreements by consensus.

For each topic for which we performed a comprehensive review (eg, the prognostic ability of home blood pressure monitoring, the prognostic ability of ambulatory blood pressure monitoring, and the adverse effects of screening for hypertension), a single reviewer extracted data from the included studies and created evidence tables. Using the guidelines developed for the USPSTF reviews, we evaluated the internal and external validity of each study (6). Experts and USPSTF members reviewed our work for accuracy and completeness at meetings in 2001 and early 2002.

# Results

## Key Question 1: Does Screening for Hypertension Reduce Cardiovascular Disease and Mortality?

RCTs of screening (versus no screening) would provide the best evidence about the effects of screening for hypertension on CVD and mortality. We identified no such studies. Many trials of hypertension treatment that compared pharmacologic and behavioral intervention to usual care, however, showed a beneficial effect of treatment in patients who were enrolled on the basis of elevated blood pressures detected on screening examinations. These findings suggest that screening may be beneficial, but examination of additional evidence is necessary to determine the value of screening. Screening would be beneficial if (1) an accurate, acceptable screening test were available to detect hypertension, (2) early treatment of hypertension resulted in better outcomes than late treatment, and (3) the balance of the potential benefits and harms were favorable.

## Key Question 2: How Can We Most Effectively Identify Patients with Hypertension for Whom Treatment Will Be Beneficial?

Hypertension, a clinically significant elevation in blood pressure, is usually defined in adults as a diastolic blood pressure (DBP) of 90 mm Hg or higher or a systolic blood pressure (SPB) of 140 mm Hg or higher (7). The Joint National Committee on Hypertension defined stage 1 hypertension as blood pressures ranging from 140 to 159 systolic or 90 to 99 diastolic, stage 2 as pressures ranging from 160 to 179 systolic or 100 to 109 diastolic, and stage 3 as those equal to or greater than 180 systolic or 110 diastolic (7).

The relative risk for adverse events associated with hypertension is continuous and graded (2,8); systolic blood pressure predicts cardiovascular risk better than diastolic pressure (9). Even modest elevations of blood pressure in young adulthood are associated with increased risk for cardiovascular events in middle age (10). The absolute risk for cardiovascular events, however, varies depending on the presence of other cardiovascular risk factors, including smoking, diabetes, and abnormal blood lipid levels, as well as the duration of blood pressure elevation (11). To determine how we can most effectively identify patients with hypertension for whom treatment will be beneficial, we consider both which screening method for detection of an elevated blood pressure is most accurate and reliable and whether screening a subset of individuals with other cardiovascular risk factors is more effective than screening everyone in targeting treatment to those who will benefit most.

### Measuring Blood Pressure Elevation in Adults: Which Screening Method Is Most Accurate and Reliable?

The accuracy and reliability of blood pressure measurement in adults depends on the method of screening. Characteristics of several common

methods of screening are described below. We are unable to provide information on test accuracy owing to limitations of existing evidence, particularly the absence of a "gold standard" against which to judge screening.

**Office Blood Pressure Measurement.** Office blood pressure measurement using an appropriate upper arm cuff with mercury or aneroid sphygmomanometry is the standard screening test for hypertension. If performed correctly, it provides a measure of blood pressure that is highly correlated with intra-arterial measurement (correlation coefficients 0.94–0.98) and is highly predictive of cardiovascular risk (12).

Although office blood pressure measurement is highly predictive when performed correctly, measurement errors occur in clinical practice (13). Errors in measuring blood pressure may result from instrument, observer, or patient factors. As noted by the USPSTF in 1996 (5)(p40): "Examples of instrument error include manometer dysfunction, pressure leaks, stethoscope defects, and cuffs of incorrect width or length for the patient's arm size. The observer can introduce errors due to sensory impairment (difficulty hearing Korotkoff sounds or reading the manometer), inattention, inconsistency in recording Korotkoff sounds (eg, Phase IV vs Phase V), and subconscious bias (eg, digit preference for numbers ending with zero or preconceived notions of "normal" pressures)." Overly rapid release of air from the blood pressure cuff may also be a problem, as may knowledge of the previous readings. Moreover, "[t]he patient can be the source of misleading readings due to posture and biologic factors. Posture (ie, lying, standing, sitting) and arm position in relation to the heart can affect results by as much as 10 mm Hg. Biologic factors include anxiety, meals, tobacco, alcohol, temperature changes, exertion, and pain." (5) In a recent systematic review of factors affecting office blood pressure measurement, McAlister and Straus documented many of the same sources of errors (14).

Because of these limitations in the precision of blood pressure measurement, experts commonly recommend that clinicians diagnose hypertension only after they obtain 2 or more elevated blood pressure readings at each of 2 or more separate visits over a period of 1 to several weeks (7). This recommendation follows the pattern of blood pressure measurement in the randomized trials that established the benefits of antihypertensive therapy and represents a compromise between reliable detection of elevated pressures and clinical practicality. One investigation using statistical modeling suggested that patients with blood pressures above 95 mm Hg or below 90 mm Hg could be accurately designated (80% confidence) as having or not having elevated blood pressure after 3 visits, whereas those with borderline elevated blood pressures required 5 visits (15). As expected, increasing precision required an increased number of measurements, particularly for those with borderline hypertension.

**Home Blood Pressure Monitoring.** Because of the greater number of measurements that can be taken at home, home blood pressure monitoring may provide a better assessment of average blood pressure than periodic office measurement. However, home blood pressure monitoring is subject to the same sources of measurement error as office blood pressure measurement. Additionally, we found only preliminary data to suggest that home monitoring may correlate better with the risk for clinical cardiovascular endpoints than office measurement (16); no definitive study is available to clarify such claims (14).

**Ambulatory Blood Pressure Measurement.** Ambulatory blood pressure monitoring provides a measure of average blood pressure over 24 hours rather than isolated single values obtained in office checks or at home. Fewer data are available about ambulatory blood pressure monitoring than about office-based blood pressure measurement (14 ,17,18). However, multiple fair quality prospective cohort studies have found that ambulatory blood pressure measurement may be a slightly better predictor of clinical cardiovascular outcomes than clinic-based approaches (19–25). Lack of good quality studies and higher monetary

costs have limited the use of ambulatory blood pressure monitoring as a screening test. Ambulatory blood pressure monitoring has, however, been useful to stratify individuals who have normal blood pressures at home but elevated blood pressures in the office, so-called white coat hypertension. A recent study by Little and colleagues examined the potential usefulness of ambulatory blood pressure monitoring in this situation (26). The study found that many patients with elevated clinic blood pressures had normal ambulatory blood pressure (<135/85).

### Determining Who Will Benefit Most: Universal vs Selective Screening for Hypertension

As previously noted, the risk for cardiovascular events and the potential benefit from screening and subsequent treatment of hypertension depend on both the degree and duration of blood pressure elevation and the presence of other cardiovascular risk factors, such as age, sex, lipid disorders, smoking, and diabetes (11,27,28). Because the degree and duration of blood pressure elevation are unknown before screening, selective screening to identify individuals who would benefit most from detection and treatment of hypertension would need to target individuals with other cardiovascular risk factors. We found no studies that examined the relative effectiveness, cost-effectiveness, or harms of targeting screening for hypertension only to those patients with other cardiovascular risk factors instead of to all patients who present at a physician's office. We additionally found no studies that examined the optimal frequency of screening based on a patient's prior blood pressure levels or other cardiovascular risk factors.

For patients who are screened, estimates of the potential benefit of treatment can be improved both by carefully measuring the degree of blood pressure elevation and by assessing the contribution of other risk factors to global cardiovascular risk (11,27,28). The feasibility of routine global risk assessment, however, has not been well studied.

## Key Question 3: How Effective Is Treatment of Hypertension (Pharmacological or Nonpharmacological) in Reducing Cardiovascular Disease Events and Mortality?

Treatment for hypertension has traditionally been defined as pharmacological or nonpharmacological therapy to reduce blood pressure. Recent trials have shown, however, that the ability of a pharmacological treatment to reduce undesirable cardiovascular outcomes may not correspond directly to its ability to lower blood pressure (29,30). We therefore separate our reviews of pharmacological and nonpharmacological therapies and focus on the efficacy of these therapies in reducing CVD events (eg, heart attacks, strokes, heart failure, and sudden death). When CVD outcomes were unavailable, we considered the effect of the intervention on blood pressure levels. Here we focus on the results of several recent high quality systematic reviews that summarize the evidence on therapy for hypertension.

### Pharmacological Treatments for Adults with Hypertension

**Stage 3 Hypertension.** A 1996 meta-analysis of 3 small trials conducted in the 1960s in patients with diastolic blood pressure (DBP) greater than 110 mm Hg found that treatment with reserpine or alpha-methyl dopa reduced the odds of congestive heart failure by 86% (odds ratio [OR] 0.14; 95% confidence interval [CI] 0.05 to 0.41) (31). Because other events were too infrequent over the 1- to 2-year durations of these trials, the authors could not determine the effects of treatment on stroke, major coronary events, CVD mortality, or total mortality. The numbers needed to treat (NNT) over 5 years ranged from 200 to 400 to prevent 1 congestive heart failure event.

**Stage 1 and Stage 2 Hypertension.** Although no studies have examined the effects of treatment only for persons with DBPs of 90 mm Hg to 99 mm Hg,

persons with DBPs of 90 to 109 mm Hg benefit from treatment. The Gueyffier et al systematic review examined 5 trials (1.4 to 7 years in duration) in individuals with DBPs of 90 mm Hg to 109 mm Hg and found that treatment of hypertension in adults younger than 60 reduced stroke (OR 0.51; 95% CI 0.39 to 0.69) but had no effect on coronary heart disease events, CVD deaths, or total mortality (31). In patients older than 60, the majority of whom had blood pressures in this range, treatment reduced total mortality (OR 0.90; 95% CI 0.81 to 1.00), CVD death (OR 0.77; 95% CI 0.67 to 0.89), stroke (OR 0.66; 95% CI 0.56 to 0.77), coronary heart disease events (OR 0.79; 95% CI 0.68 to 0.92) and congestive heart failure (OR 0.54; 95% CI 0.43 to 0.68)(31). The numbers needed to treat over 5 years ranged from approximately 900 to prevent 1 stroke to 10,000 to prevent 1 case of coronary heart disease event or death.

**Isolated Systolic Hypertension in the Elderly.** Staessen et al recently performed a systematic review of 8 trials, including two published since 1996, comparing treatment of isolated systolic hypertension (systolic blood pressure [SBP] greater than 160 mm Hg but DBP less than 95 mm Hg) in patients older than 60 with pharmacological therapy (eg, diuretics, beta-blockers, or calcium-channel blockers) or with placebo treatment (28). The authors found that active treatment reduced stroke (RR 0.70; 95% CI 0.59 to 0.82), coronary heart disease events (RR 0.70; 95% CI 0.66 to 0.90), CVD mortality (RR 0.82; 95% CI 0.71 to 0.96), and total mortality (RR 0.87; 95% CI 0.78 to 0.98). The number needed to treat over 5 years to prevent 1 cardiovascular event was 18 (95% CI 17 to 19) in men and 38 (95% CI 36 to 40) in women.

### Nonpharmacological Therapies in Adults

RCTs of nonpharmacological therapies have examined CVD events as outcomes. Fair to good evidence supports the effectiveness of several nonpharmacological interventions for reducing blood pressure in patients with hypertension over periods up to 1 to 2 years (eg, weight reduction in overweight patients (32–34), increased physical activity (35), sodium reduction (36–43), potassium supplementation (44–47), decreased alcohol intake (48), and stress management (49)(50,51). The magnitude of blood pressure reduction differs by intervention, ranging from 2 to 15 mm Hg for studied interventions: 4–15 mm Hg reduction in SBP for 2–10 kg weight reduction (32); 5–7 mm Hg reduction in SBP with moderate to vigorous exercise (35); 5.8 mm Hg reduction in SBP with 100 mmol/L (1 teaspoon) reduction in salt intake (36); 3.1 mm Hg reduction in SBP with 60 mmol (= 60 meq) of potassium supplementation (44); 3.3 mm Hg reduction in SBP with 50% reduction in alcohol use in persons drinking 20–40 drinks/week (48); and 9–10 mm Hg reduction in SBP for persons receiving single or multi-component stress management interventions (49). Importantly, some of these interventions (eg, weight reduction, physical activity) have other beneficial effects that may not be mediated through changes in blood pressure or changes in the incidence of cardiovascular events.

Nonpharmacological therapy also appears to be effective for the primary prevention of hypertension. This topic is outside the scope of our review; we refer the reader to a recent review by the National High Blood Pressure Education Program (52) for more information.

## Key Question 4: What Are the Adverse Effects of Screening and Treatment for Hypertension?

### Adverse Effects of Screening for Hypertension

We identified 10 cohort studies examining the adverse effects of screening for hypertension and subsequently labeling a person as "hypertensive." These studies were reported in 14 papers and used multiple study designs (53–66). Some studies compared the consequences of screening in hypertensive persons who previously were either aware or unaware of their hypertension; these studies addressed the differential effects of screening and diagnosis versus monitoring of hypertension.

Others compared the unintended consequences of labeling an individual as "hypertensive" versus "normotensive." We identified no studies that compared the effect of labeling or not labeling all individuals who were identified to have high blood pressure.

We identified 6 cohort studies examining the psychological effects of screening and labeling individuals with hypertension (53–59). Five compared the unintended psychological effects of labeling an individual as "hypertensive" or "normotensive" (53–58); 1 compared the psychological effects of screening and labeling hypertensive individuals who previously were either aware or unaware of their hypertensive diagnosis (59). These studies did not find any evidence for adverse psychological effects. However, 3 of these studies had high attrition rates (53,54,56,57); 1 reported no statistical comparisons (59,67); and 1 reported only within-group changes in absenteeism among those who were newly diagnosed with hypertension (55).

One retrospective and 4 prospective cohort studies showed an increase in absenteeism of 2.2 days to 5.7 days per year in newly screened and diagnosed individuals (59–65). One study, however, reported no statistical comparisons of absenteeism among groups (59,67); 2 reported only within group statistical comparisons of absenteeism among those who were previously unaware of their hypertensive diagnosis, making no comparisons with the control group of aware hypertensives (60,61,65); and 1 showed only a trend toward a statistical increase in absenteeism among patients who were previously unaware (compared with aware) of their diagnosis of hypertension (62). Two other cohort studies did not find an increase in absenteeism (56–58), although the study by Rudd and colleagues was again noted to have high attrition rates, which limited conclusions. Differences in the way absenteeism has been defined may explain these discrepancies. In many cases, the reasons for work absenteeism were not directly measured, and absenteeism may be explained by visits to a medical provider for the treatment of hypertension. Additionally, many studies did not control for the effects of comorbid illness or the complications of hypertension, nor did they report how patients were informed of their blood pressure status.

In summary, we found fair quality evidence suggesting that screening and labeling adults with hypertension produces no adverse effects on psychological well-being and mixed effects on absenteeism rates for jobs.

### Adverse Effects of Treatment of Hypertension

Serious or life-threatening adverse drug reactions have been rare in clinical trials of drugs for hypertension, particularly in those that have used low-dose regimens. Less serious adverse effects have been noted to occur with most drugs (68). A full review of these effects is beyond the scope of this report, but it is clear that clinicians should take adverse effects into account when deciding whether to treat and which treatment to use because the majority of patients with hypertension are asymptomatic.

## Discussion

Strong indirect evidence supports screening adults for hypertension. Hypertension is an important contributor to CVD morbidity and mortality. It is predictive of CHD events and is reliably detected through screening blood pressure measurements using a standard arm blood pressure cuff and sphygmomanometer. Additionally, treatment of adult hypertensive patients with drug therapy and possibly nonpharmacological interventions can reduce blood pressure and the incidence of cardiovascular events, including myocardial infarction, heart failure, and stroke. The degree of risk reduction depends on patients' levels and possibly duration of blood pressure elevation, their other risk factors for CVD, and the choice of antihypertensive treatment.

This review extends our knowledge about several specific questions germane to hypertension screening. Recent prospective studies suggest that ambulatory blood pressure monitoring may be a better predictor of cardiovascular risk than clinic

blood pressure measurement, although its utility for screening remains uncertain. Recent treatment trials have confirmed large potential benefit in detecting and treating isolated systolic hypertension in the elderly, highlighting the importance of screening and treating older adults. A detailed analysis of studies addressing the potential harms of hypertension screening found no evidence of adverse effects on psychological well-being and evidence of mixed effects on absenteeism rates in those who are screened and labeled.

Although substantial indirect evidence supports screening, many important issues about screening remain unanswered. Among the high priority questions are the following:

- Is selective screening based on age, previous blood pressure levels, and the presence of other risk factors more cost-effective than screening all patients for elevated blood pressure at each clinic visit?
- How predictive and reliable is home monitoring of blood pressure (compared to office monitoring) in predicting the risk for future cardiovascular events?
- Is ambulatory blood pressure monitoring an effective and cost-effective means of identifying patients for treatment?
- What is the optimal approach to patients who report normal blood pressure levels at home but have elevated blood pressure in the office (white coat hypertension)?
- Are there adverse consequences from labeling someone with hypertension in addition to the ones discussed here?

Additionally, despite relatively clear evidence supporting screening and the widespread use of clinical blood pressure measurement, identification and treatment of hypertension remains suboptimal for the U.S. population as a whole. A recent population-based study using National Health and Nutrition Exam Survey (NHANES III) data reported that 31% of hypertensive Americans are unaware that they have hypertension, 17% are aware of their diagnosis but are not being treated, and 29% are being treated but have not controlled their blood pressure (69). *Healthy People 2010* aims to reduce all of these numbers to 5% (70). Substantial progress in organization of care and access to care will be required to approach the *Health People 2010* goals.

## Acknowledgments

This study was developed by the RTI International-University of North Carolina at Chapel Hill (RTI-UNC) Evidence-Based Practice Center under contract to the Agency for Healthcare Research and Quality (AHRQ) (contract #290-97-0011), Rockville, Maryland. We acknowledge at AHRQ the continuing support of David Atkins, MD, MPH, Chief Medical Officer of the AHRQ Center for Practice and Technology Assessment; and Jean Slutsky, PA, MSPH, Task Order Officer for the USPSTF project.

We are also indebted to our U.S. Preventive Services Task Force liaisons: Mark Johnson, MD, MPH, UMD-New Jersey Medical School, Newark, NJ; Jonathan Klein, MD, MPH, University of Rochester, Rochester, NY; Nola Pender, PhD, RN, FAAN, University of Michigan, Ann Arbor, MI; Cynthia Mulrow, MD, MSc, National Program Office for Robert Wood Johnson Generalist Physician Faculty Scholars Program and The University of Texas Health Science Center, San Antonio, TX, for the guidance and substantive contributions.

The investigators deeply appreciate the considerable support and contributions of members of the RTI International staff: Kathleen N. Lohr, PhD, EPC Co-director, for technical review and editing of this summary of the evidence, Linda Lux, MPA, for substantive assistance and technical review, Sonya Sutton, BSPH, for substantive and editorial work, and Loraine Monroe, for superior secretarial assistance. In addition, we are indebted to staff from the University of North Carolina at Chapel Hill and the Cecil G. Sheps Center for Health Services Research: Carol Krasnov for diligent administrative assistance and coordination, and Timothy S. Carey, MD, MPH, Director of the Sheps Center and Co-Director of the RTI-UNC Evidence-based Practice Center.

This article is based on a more comprehensive systematic review available online at www.ahrq.gov. That document was reviewed by the following content experts to whom we are grateful for their insightful comments and suggestions: Curt Furberg, MD, PhD, Wake Forest University School of Medicine, Winston-Salem, NC; Matthew Gillman, MD, SM, Harvard School of Public Health, Boston, MA; and Lee Green, MD, MPH, University of Michigan, Ann Arbor, MI.

## References

1. Padwal R, Straus SE, McAlister FA. Evidence based management of hypertension. Cardiovascular risk factors and their effects on the decision to treat hypertension: evidence based review. *BMJ.* 2001;322 (7292):977–980.

2. Kannel WB. Blood pressure as a cardiovascular risk factor: prevention and treatment. *JAMA.* 1996;275(20):1571–1576.

3. Klein R, Klein BE, Moss SE. The relation of systemic hypertension to changes in the retinal vasculature: the Beaver Dam Eye Study. *Trans Am Ophthalmol Soc.* 1997;95:329–348; discussion 348–350.

4. Lederle FA, Johnson GR, Wilson SE, Chute EP, Littooy FN, Bandyk D, et al. Prevalence and associations of abdominal aortic aneurysm detected through screening. Aneurysm Detection and Management (ADAM) Veterans Affairs Cooperative Study Group. *Ann Intern Med.* 1997;126(6) :441–449.

5. U.S. Preventive Services Task Force. *Guide to Clinical Preventive Services*, 2nd ed. Washington, DC: Office of Disease Prevention and Health Promotion; 1996. "Screening for hypertension," pp. 39–51.

6. Harris RP, Helfand M, Woolf SH, et al. Current methods of the U.S. Preventive Services Task Force: a review of the process. *Am J Prev Med.* 2001;20(3 Suppl):21–35.

7. The Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. *Arch Intern Med.* 1997;157(21):2413–2446.

8. Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet.* 2002;360:1903–1913.

9. Benetos A, Thomas F, Bean K, Gautier S, Smulyan H, Guize L. Prognostic value of systolic and diastolic blood pressure in treated hypertensive men. *Arch Intern Med.* 2002;162(5):577–581.

10. Miura K, Daviglus ML, Dyer AR, et al. Relationship of blood pressure to 25-year mortality due to coronary heart disease, cardiovascular diseases, and all causes in young adult men: the Chicago Heart Association Detection Project in Industry. *Arch Intern Med.* 2001;161(12):1501–1508.

11. Ferrucci L, Furberg CD, Penninx BW, et al. Treatment of isolated systolic hypertension is most effective in older patients with high-risk profile. *Circulation.* 2001;104(16):1923–1926.

12. Reeves RA. Does this patient have hypertension? How to measure blood pressure. *JAMA.* 1995; 273(15):1211–1218.

13. Birkett NJ. The effect of alternative criteria for hypertension on estimates of prevalence and control. *J Hypertens.* 1997;15(3):237–244.

14. McAlister FA, Straus SE. Evidence based treatment of hypertension. Measurement of blood pressure: an evidence based review. *BMJ.* 2001;322(7291): 908–911.

15. Perry HM Jr, Miller JP. Difficulties in diagnosing hypertension: implications and alternatives. *J Hypertens.* 1992;10(8):887–896.

16. Ohkubo T, Imai Y, Tsuji I, et al. Prediction of mortality by ambulatory blood pressure monitoring versus screening blood pressure measurements: a pilot study in Ohasama. *J Hypertens.* 1997;15(4): 357–364.

17. Myers MG, Haynes RB, Rabkin SW. Canadian hypertension society guidelines for ambulatory blood pressure monitoring. *Am J Hypertens.* 1999;12(11 Pt 1):1149–1157.

18. Staessen JA, Beilin L, Parati G, Waeber B, White W. Task force IV: Clinical use of ambulatory blood pressure monitoring. Participants of the 1999 Consensus Conference on Ambulatory Blood Pressure Monitoring. *Blood Press Monit.* 1999;4(6):319–331.

19. Perloff D, Sokolow M, Cowan R. The prognostic value of ambulatory blood pressures. *JAMA.* 1983;249(20):2792–2798.

20. Khattar RS, Senior R, Lahiri A. Cardiovascular outcome in white-coat versus sustained mild hypertension: a 10-year follow-up study. *Circulation.* 1998;98(18):1892–1897.

21. Redon J, Campos C, Narciso ML, Rodicio JL, Pascual JM, Ruilope LM. Prognostic value of ambulatory blood pressure monitoring in refractory hypertension: a prospective study. *Hypertension.* 1998;31(2):712–718.

22. Verdecchia P, Porcellati C, Schillaci G, et al. Ambulatory blood pressure. An independent predictor of prognosis in essential hypertension. *Hypertension.* 1994;24(6):793–801.

23. Ohkubo T, Imai Y, Tsuji I, et al. Reference values for 24-hour ambulatory blood pressure monitoring based on a prognostic criterion: the Ohasama Study. *Hypertension.* 1998;32(2):255–259.

24. Khattar RS, Swales JD, Banfield A, Dore C, Senior R, Lahiri A. Prediction of coronary and cerebrovascular morbidity and mortality by direct continuous ambulatory blood pressure monitoring in essential hypertension. *Circulation.* 1999;100(10): 1071–1076.

25. Staessen JA, Thijs L, Fagard R, et al. Predicting cardiovascular risk using conventional vs. ambulatory blood pressure in older patients with systolic hypertension. Systolic Hypertension in Europe Trial Investigators. *JAMA.* 1999;282(6):539–546.

26. Little P, Barnett J, Barnsley L, Marjoram J, Fitzgerald-Barron A, Mant D. Comparison of agreement between different measures of blood pressure in primary care and daytime ambulatory blood pressure. *BMJ.* 2002;325(7358):254.

27. Ogden LG, He J, Lydick E, Whelton PK. Long-term absolute benefit of lowering blood pressure in hypertensive patients according to the JNC VI risk stratification. *Hypertension.* 2000;35(2):539–543.

28. Staessen JA, Gasowski J, Wang JG, et al. Risks of untreated and treated isolated systolic hypertension in the elderly: meta-analysis of outcome trials. *Lancet.* 2000;355(9207):865–872.

29. Yusuf S, Sleight P, Pogue J, Bosch J, Davies R, Dagenais G. Effects of an angiotensin-converting-enzyme inhibitor, ramipril, on cardiovascular events in high-risk patients. The Heart Outcomes Prevention Evaluation Study Investigators. *N Engl J Med.* 2000; 342(3):145–153.

30. ALLHAT Collaborative Research Group. Major cardiovascular events in hypertensive patients randomized to doxazosin vs chlorthalidone: the antihypertensive and lipid-lowering treatment to prevent heart attack trial (ALLHAT). *JAMA.* 2000;283(15):1967–1975.

31. Gueyffier F, Froment A, Gouton M. New meta-analysis of treatment trials of hypertension: improving the estimate of therapeutic benefit. *J Hum Hypertens.* 1996;10(1):1–8.

32. Leiter LA, Abbott D, Campbell NR, Mendelson R, Ogilvie RI, Chockalingam A. Lifestyle modifications to prevent and control hypertension. Recommendations on obesity and weight loss. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. *CMAJ.* 1999;160(9 Suppl):S7–S12.

33. Jones DW. Body weight and blood pressure. Effects of weight reduction on hypertension. *Am J Hypertens.* 1996;9(8):50s–54s.

34. Blumenthal JA, Sherwood A, Gullette EC, et al. Exercise and weight loss reduce blood pressure in men and women with mild hypertension: effects on cardiovascular, metabolic, and hemodynamic functioning. *Arch Int Med.* 2000;160(13):1947–1958.

35. Cleroux J, Feldman RD, Petrella RJ. Lifestyle modifications to prevent and control hypertension. Recommendations on physical exercise training. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. *CMAJ.* 1999;160(9 Suppl):S21–S8.

36. Midgley JP, Matthew AG, Greenwood CM, Logan AG. Effect of reduced dietary sodium on blood pressure: a meta-analysis of randomized controlled trials. *JAMA.* 1996;275(20):1590–1597.

37. Hooper L, Bartlett C, Davey Smith G, Ebrahim S. Systematic review of long term effects of advice to reduce dietary salt in adults. *BMJ.* 2002; 325(7365):628.

38. Ebrahim S, Smith GD. Lowering blood pressure: a systematic review of sustained effects of non-pharmacological interventions. *J Public Health Med.* 1998;20(4):441–448.

39. Fodor JG, Whitmore B, Leenen F, Larochelle P. Lifestyle modifications to prevent and control hypertension. Recommendations on dietary salt. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. *CMAJ.* 1999;160(9 Suppl):S29–S34.

40. Cutler JA, Follmann D, Allender PS. Randomized trials of sodium reduction: an overview. *Am J Clin Nutr.* 1997;65(2 Suppl):643S–651S.

41. Neaton JD, Grimm RH Jr, Prineas RJ, et al. Treatment of mild hypertension study. Final results. Treatment of mild hypertension study research group. *JAMA.* 1993;270(6):713–724.

42. Appel LJ, Moore TJ, Obarzanek E, et al. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. *N Engl J Med.* 1997;336(16):1117–1124.

43. Sacks FM, Svetkey LP, Vollmer WM, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. *N Engl J Med.* 2001;344(1):3–10.

44. Whelton PK, He J, Cutler JA, et al. Effects of oral potassium on blood pressure. Meta-analysis of randomized controlled clinical trials. *JAMA.* 1997;277(20):1624–1632.

45. Gilleran G, O'Leary M, Bartlett WA, Vinall H, Jones AF, Dodson PM. Effects of dietary sodium substitution with potassium and magnesium in hypertensive type II diabetics: a randomised blind controlled parallel study. *J Hum Hypertens.* 1996;10(8):517–521.

46. Fotherby MD, Potter JF. Long-term potassium supplementation lowers blood pressure in elderly hypertensive subjects. *Int J Clin Pract.* 1997;51(4): 219–222.

47. Kawano Y, Minami J, Takishita S, Omae T. Effects of potassium supplementation on office, home, and 24-h blood pressure in patients with essential hypertension. *Am J Hypertens.* 1998;11(10):1141–1146.

48. Xin X, He J, Frontini MG, Ogden LG, Motsamai OI, Whelton PK. Effects of alcohol reduction on blood pressure: a meta-analysis of randomized controlled trials. *Hypertension.* 2001;38(5): 1112–1117.

49. Linden W, Chambers L. Clinical effectiveness of non-drug treatment for hypertension: a meta-analysis. *Ann Behav Med.* 1994;16:35–45.

50. Spence JD, Barnett PA, Linden W, Ramsden V, Taenzer P. Lifestyle modifications to prevent and control hypertension. Recommendations on stress management. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. *CMAJ.* 1999;160 (9 Suppl):S46–S50.

51. Batey DM, Kaufmann PG, Raczynski JM, et al. Stress management intervention for primary prevention of hypertension: detailed results from Phase I of Trials of Hypertension Prevention (TOHP-I). *Ann Epidemiol.* 2000;10(1):45–58.

52. Whelton PK, He J, Appel LJ, et al. Primary prevention of hypertension: clinical and public health advisory from The National High Blood Pressure Education Program. *JAMA.* 2002; 288(15):1882–1888.

53. Ameling EH, de Korte DF, Man in 't Veld A. Impact of diagnosis and treatment of hypertension on quality of life: a double-blind, randomized, placebo-controlled, cross-over study of betaxolol. *J Cardiovasc Pharmacol.* 1991;18(5):752–760.

54. Mann AH. The psychological effect of a screening programme and clinical trial for hypertension upon the participants. *Psychol Med.* 1977;7(3):431–438.

55. Ambrosio GB, Dissegna L, Zamboni S, Santonastaso P, Canton G, Dal Palu C. Psychological effects of hypertension labeling during a community survey. A two-year follow-up. *J Hypertens Suppl.* 1984;2(3):S171–S3.

56. Rudd P, Price MG, Graham LE, et al. Consequences of worksite hypertension screening. Differential changes in psychosocial function. *Am J Med.* 1986;80(5):853–860.

57. Rudd P, Price MG, Graham LE, et al. Consequences of worksite hypertension screening. Changes in absenteeism. *Hypertension.* 1987;10(4):425–436.

58. Rastam L, Ryden L. Work absenteeism and well-being in patients treated for hypertension. *Eur Heart J.* 1987;8(9):1024–1031.

59. Polk BF, Harlan LC, Cooper SP, et al. Disability days associated with detection and treatment in a hypertension control program. *Am J Epidemiol.* 1984;119(1):44–53.

60. Haynes RB, Sackett DL, Taylor DW, Gibson ES, Johnson AL. Increased absenteeism from work after detection and labeling of hypertensive patients. *N Engl J Med.* 1978;299(14):741–744.

61. Taylor DW, Haynes RB, Sackett DL, Gibson ES. Longterm follow-up of absenteeism among working men following the detection and treatment of their hypertension. *Clin Invest Med.* 1981;4(3–4):173–177.

62. Charlson ME, Alderman M, Melcher L. Absenteeism and labeling in hypertensive subjects. Prevention of an adverse impact in those at high risk. *Am J Med.* 1982;73(2):165–170.

63. Johnston ME, Gibson ES, Terry CW, et al. Effects of labeling on income, work and social function among hypertensive employees. *J Chronic Dis.* 1984;37(6):417–423.

64. Alderman MH, Charlson ME, Melcher LA. Labeling and absenteeism: the Massachusetts Mutual experience. *Clin Invest Med.* 1981;4(3–4):165–171.

65. Alderman MH, Melcher LA. Occupationally-sponsored, community-provided hypertension control. *J Occup Med.* 1983;25(6):465–470.

66. Stenn PG, Noce A, Buck C. A study of the labeling phenomenon in school children with elevated blood pressure. *Clin Invest Med.* 1981;4(3–4):179–181.

67. Harlan LC, Polk BF, Cooper S, et al. Effects of labeling and treatment of hypertension on perceived health. *Am J Prev Med.* 1986;2(5):256–261.

68. Mulrow CD, Pignone M. How do we best individualize treatment for patients based on their cardiovascular risk profile? In: Mulrow CD, ed. *Evidence-based Hypertension.* London: BMJ Publishing Group; 2001:117–130.

69. Hyman DJ, Pavlik VN. Characteristics of patients with uncontrolled hypertension in the United States. *N Engl J Med.* 2001;345(7):479–486.

70. U.S. Department of Health and Human Services. *Healthy People 2010*. With Understanding and Improving Health and Objectives for Improving Health. 2nd ed. Washington, DC: U.S. Government Printing Office; 2000.

AHRQ Pub. No. 03-0522B
June 2003