Prevention of hypertension
Michel Slama, MD, Dinko Susic, MD, PhD, and Edward D. Frohlich, MD

Hypertension is a major risk factor for many cardiovascular diseases including stroke, coronary heart disease, cardiac failure, and endstage renal disease. Therefore, prevention of hypertension becomes an important goal in overall efforts to control blood pressure and reduce the incidence of hypertension-related cardiovascular and renal complications and outcomes. Many risk factors underlying hypertension have been identified including nonmodifiable factors such as age, gender, genetic factors, and race, as well as modifiable factors including overweight, high sodium intake, low potassium intake, alcohol consumption, and reduced physical activity. A number of studies have demonstrated that interventions aimed at changing these modifiable factors might decrease blood pressure and even prevent the development of hypertension. Thus, present national recommendations and guidelines include lifestyle modifications ranging from weight loss in case of obesity, engagement in regular isotonic physical activity, reduced sodium diet (<100 mmol/d), supplementation of potassium, and alcohol moderation (<1 ounce of ethanol or its equivalent per day). Curr Opin Cardiol 2002, 17:531–536 © 2002 Lippincott Williams & Wilkins, Inc.

Cardiovascular diseases are the major cause of death in industrialized societies, and hypertension is the major treatable risk factor of these cardiovascular disorders including stroke, coronary heart disease, cardiac failure, and endstage renal disease [1–3]. Consequently, the management of hypertension appears to be one of the major therapeutic goals. It should be emphasized that the percentage of hypertensives in the general population who are identified, are under treatment, and whose arterial pressure are under control remain unacceptable, yet the prevalence of hypertension slowly but progressively seems to have decreased over the past 20 years [4]. The importance of hypertension management is further stressed by National and World Health Organization Guidelines on prevention, detection, evaluation, and treatment of high blood pressure [5,6]. An interesting analysis of the impact of small reduction in diastolic pressure further stresses the role of hypertension in overall cardiovascular morbidity and mortality [7,8]. Thus, Cook et al. demonstrated that a reduction in diastolic pressure of only 2 mm Hg results in a 17% reduction in the prevalence of hypertension, with consequent reduction in the risks of stroke, transient ischemic attacks, coronary heart disease, and congestive heart failure [8]. Similarly, reduction of systolic pressure decreases the incidence of these consequences of the hypertension, perhaps even more [8]. Apparently, treatment of hypertension alone is not always sufficient; adverse drug effects, patient adherence, and failure in detection, and pressure control limit the efficiency of this approach. Moreover, even if the pressure is well controlled with a drug therapy, the consequences of hypertension are reduced but may not be eliminated. Therefore, the primary prevention of hypertension appears an extremely important part of the overall management of cardiovascular diseases.

Epidemiological studies have identified a number of risk factors underlying hypertension including age, gender, family history of hypertension, African-American ancestry, overweight, diabetes mellitus, excess consumption of sodium, physical inactivity, smoking, and excess coffee and alcohol consumption [6]. These risk factors can be divided into two groups: factors that are not modifiable, such as age, gender, ethnicity, and genetic factors; and other factors can be modified and in this way may decrease or even prevent hypertension. It is the purpose of this report to summarize briefly certain recent reports on some of these modifiable risk factors. Our emphasis...
will be on primary prevention of hypertension by modification of some of these risk factors, a goal that until recently has been considered only a dream.

Nonmodifiable factors

Aging
Arterial pressure tends to increase with aging in most populations, thus increasing the incidence and prevalence of hypertension in the elderly. This increase in pressure most often involves systolic and pulse pressures, whereas diastolic pressure tends even to decrease or remain at the same level. The relation between age and blood pressure has been demonstrated in many cross-sectional or longitudinal studies. In the Framingham Heart Study, the biennial incidence of hypertension was shown to increase from 3.3% in men between 50 and 59 years of age to 6.2% in men between 70 and 79, and from 1.5% to 8.6% in women of comparable ages [7]. The prevalence of hypertension also increases with age; it is about 25% in 40- to 50-year-old men and increased to well over 50% after the age of 60 [4]. Although very common in elderly people, hypertension must also be considered pathologically. Thus, it has been clearly demonstrated that an elevated arterial pressure is accompanied by an increased risk of stroke, coronary heart disease, heart failure, and end-stage renal disease. Moreover, treatment of isolated systolic hypertension, the most common type of hypertension in the elderly, drastically decreases the incidence of these complications [9].

Ethnicity
Ethnicity also plays an important role in the pathogenesis of hypertension, and the prevalence of hypertension is higher in African-Americans than in other ethnic groups. This has been documented in earlier studies and has been recently confirmed by the National Health and Nutrition Examination Survey [4,5,10–12]. On the other hand, one recent report demonstrated that African-Americans and whites have similar risks of developing hypertension at the same given age, regardless of the initial arterial pressure level or body mass index [13]. This latter study was conducted in middle-aged subjects over a period of 7 years. It should be noted, however, that the study was performed in selected population. All participants were employed and had higher socioeconomic status compared with the general population. Many explanations have been advanced to explain higher susceptibility of African-Americans to hypertension. These include genetic susceptibility to increased vasoactivity and reduced vasodilatation [14,15]. As for the other ethnic groups, the incidence of hypertension has been reported to be comparable in Mexican-Americans and non-Hispanic whites but was lower in Asian-Americans [13].

Gender
The prevalence and incidence of hypertension is slightly higher in men compared with women. This gender difference is greater in the young and middle-aged population, but it decreases or even reverses in older subjects [4].

Modifiable (environmental) factors

Body mass
A relation between body mass and arterial pressure has been well established in both cross-sectional and longitudinal studies [16]. Recently, large interventional trials demonstrated a decrease in the incidence of hypertension and reduction in systolic and diastolic pressures after reducing body weight. In the Hypertension Prevention Trial, a 4% reduction in body weight over 3 years resulted in a decrease in both systolic and diastolic pressures (of −2.4 to −1.8 mm Hg, respectively) [17]. Similarly, the TOHP-I study, conducted in a cohort of 35- to 54-year-old men and women, demonstrated a reduction of 2.9 and 2.3 mm Hg in systolic and diastolic arterial pressure, respectively, after a weight loss of 3.9 kg over an 18-month period of follow-up [18]. It is also important to the thesis of this discussion that, simultaneously, a 51% reduction in the incidence of hypertension was also shown [18]. In a recent analysis of 7-year follow-up of the Trial of Hypertension Prevention (Phase I) group, He et al. reported that in parallel with weight loss, the incidence of hypertension was reduced by 77% [19]. Moreover, in phase II of this study [20•], and in the study conducted by Kriketos et al. [21] even modest weight loss diminished the risk of hypertension. In these studies, a weight loss of 4.5 kg decreased the relative risk of hypertension by 65%. It should be noted that there were individual differences in the efficacy of weight loss to decrease arterial pressure, which have been most often attributed to sympathetic overactivity and angiotensinogen genotype [22•, 23].

Dietary sodium reduction
Increased sodium intake is a well-demonstrated risk factor for hypertension [24]. Furthermore, in hypertensive patients, sodium restriction results in a significant blood pressure reduction [25•]. There have been more than 60 randomized studies that have analyzed the effect of dietary sodium on arterial pressure and the incidence of hypertension [26,27]. Thus, 28 trials were pooled by Midgley et al. [26] and 12 by Cutler et al. in two meta-analyses [27]. There were 2374 normotensive participants included in one meta-analysis [26] and 1689 in the other [27]. In these two reports, reduction in dietary sodium intake resulted in a reduction of both systolic (from 1.6 to 1.9 mm Hg) and diastolic (from 0.5 to 1.1 mm Hg) pressures. It should be noted that most of the studies included in these two meta-analyses were short term. In a recent 18-month study, He et al. demonstrated a net reduction (compared with the control group) of 3.3 mm
Hg and 1.7 mm Hg for systolic and diastolic arterial pressure, respectively [19]. A decreased incidence of hypertension was also observed. Over 7 years of follow-up, the odds of developing hypertension were reduced by 35%. Therefore, taken together, these findings suggest that reduced sodium intake in the general population (and particularly in the subgroups with high risk of developing hypertension) has been extremely useful in preventing hypertension.

### Alcohol consumption

Epidemiological and experimental investigations have established a close association between alcohol consumption and hypertension [28]. A linear dose–response relation has been reported in some studies with a consumption threshold of three drinks per day. In other studies, this relation was found to be nonlinear, especially in women. Moreover, a few studies suggested that a small quantity of alcohol (less than 1 ounce of ethanol daily) might actually reduce arterial pressure [29,30•]. Recently, Fuchs et al. studied alcohol consumption and the incidence of hypertension in 8334 black and white American men and women in a 6-year follow-up [30•]. The risk of developing hypertension was found to be higher in all subjects when the alcohol consumption was greater than 210 g per week. Intake of lesser quantity of ethanol was a risk factor for hypertension only in black men [30•]. Furthermore, a nonlinear relation was found between arterial pressure and alcohol consumption. The results of a recent meta-analysis involving 15 randomized, controlled trials with 2234 participants were similar [31••]. Moreover, reduction in alcohol consumption was associated with a mean decrease of 3.31 mm Hg for the systolic pressure and 2.04 mm Hg for the diastolic blood pressure. Taken together, results suggest that reduction of alcohol consumption in the general population can be an efficient way to prevent hypertension.

### Potassium supplementation

Most epidemiological studies suggest an inverse relation between potassium intake and blood pressure [16], although some do not support this notion. Thus, in a recent analysis of 2358 participants of the Framingham Heart Study, Walsh et al. did not relate serum potassium and subsequent development of hypertension [32]. On the other hand, Bazzano et al. demonstrated that a low dietary potassium intake was associated with an increased risk of stroke [33]. Many other studies have evaluated the effect of oral potassium supplementation on blood pressure. A meta-analysis involving 33 different studies with 2609 participants demonstrated that potassium supplementation significantly reduced both systolic and diastolic pressure by 3.11 and 1.97 mm Hg, respectively [34]. Two recent analyses, performed on African-American and Chinese populations in whom the potassium consumption was usually low, also confirmed these findings [35,36]. Therefore, it appears that increased oral potassium intake should also be recommended for prevention of hypertension.

### Calcium and magnesium supplementation

The relation between calcium intake and blood pressure has been strongly established, but the effect of calcium supplementation remains unclear. In one meta-analysis, Allender et al. reported significantly decreasing systolic pressure with calcium supplementation in patients with hypertension but not in normotensive participants [37]. On the other hand, in the trial of Hypertension Prevention Collaborative Research Group and the TOHP studies, there was no effect of calcium supplementation at 3-, 6-, or 18-month follow-up [38,39]. In another meta-analysis of six studies conducted in normotensive participants, Bucher et al. reported no effect of calcium supplementation [40]. The results concerning the effects of magnesium intake on arterial pressure are also unclear [41]. Therefore, at present, calcium or magnesium supplementation as a means to prevent hypertension has not been established.

### Other dietary modifications

Coffee drinking has been suspected as a risk factor for hypertension for a long time. A meta-analysis involving 11 randomized studies with 522 participants and median follow-up of 56 days has been recently published [42•]. An increased diastolic and systolic pressures was found (1.2 and 2.4 mm Hg, respectively) in coffee drinkers. For every cup of coffee consumed, systolic pressure increased by 0.8 mm Hg and diastolic pressure by 0.5 Hg. In a very recent long-term study, Klag et al. examined 1017 white men over a follow-up of 33 years [43]. A consumption of one cup of coffee a day significantly raised systolic and diastolic pressure (0.19 and 0.27 mm Hg, respectively) and the incidence of hypertension was higher in coffee drinkers than in nondrinkers (28.3 vs 18.8, \( P = 0.03 \)).

Fish oil supplementation has also been proposed to prevent hypertension. In one meta-analysis, Appel et al. examined 11 trials in normotensive participants and found a small reduction in the systolic pressure (1 mm Hg) in subjects given fish oil [44]. More recently, in a study by Whelton et al., there was no effect of omega-3 polyunsaturated fatty acids on blood pressure [38]. In a randomized, prospective, and double-blinded study, omega-3 fatty acids supplementation ameliorated a long-term continuous rise in arterial pressure in a particular subgroup of hypertensive subjects after heart transplantation [45]. Furthermore, renal function was also preserved in this population [45]. Nevertheless, at this time fish oil supplementation does not seem to prevent hypertension in the general population.

The effect of a diet with low-fat dairy foods having reduced saturated and total fats has also been tested in a
prospective and randomized study involving 459 adults with a systolic and diastolic blood pressure less than 160/95 mm Hg [46]. After 8 weeks, systolic and diastolic pressures were reduced by 5 and 3 mm Hg, respectively [46], but pressure reduction was also noted in the control group [46].

Many epidemiological studies also found an inverse relation between dietary fiber and arterial pressure [47]. To analyze the effect of dietary fiber supplementation, He and Whelton pooled randomized controlled studies. In these studies, the average of supplementation per day was 14 g and was provided in most studies from cereals. A significant reduction of systolic and diastolic pressure was reported (1.6 and 2 mm Hg, respectively) [47]. Similarly, in the DASH study, a group of subjects receiving a diet rich in fruits and vegetables also had a reduction of blood pressure [48].

An inverse relation was found between dietary protein intake and blood pressure in an observational study conducted in United States [49]. In another study, conducted in China, a higher intake of total dietary protein was associated with a lower systolic and diastolic pressure [50].

Physical activity and stress management
Most epidemiological studies have shown that increased physical activity was associated with reduced arterial pressure [16,51]. In a recent meta-analysis, Whelton et al. reported the effect of aerobic exercise on arterial pressure [52••]. This form of physical activity was associated with a significant reduction of systolic and diastolic pressure (~3.35 and ~2.58 mm Hg, respectively), an effect observed in both hypertensive and normotensive subjects as well as in overweight and normal-weight participants. Similarly, in young subjects with mild hypertension, physical activity lowered arterial pressure [53]. It appears that the type of physical activity might be important in determining its effect on arterial pressure. Thus, Hernelahti et al. found a decreased incidence of hypertension in elite athletes in endurance or mixed sports when compared with athletes in power sports or control subjects [54]. Therefore, physical activity (endurance, aerobic) should be recommended to reduce pressure and the incidence of hypertension, although some further information is warranted.

Finally, the effect of stress on arterial pressure has been suspected for a long time [55–57]. Although the Framingham study [55] supports this hypothesis, new findings suggested that stress has negligible effect on pressure [56,57]. The results of interventional studies on the effect of stress management on arterial pressure in hypertensive subjects are conflicting [58–60]. A most recent prevention study did not find any effect of stress management on arterial pressure [61].

Smoking
It is clear that smoking is an important risk factor underlying coronary heart disease, and it is a major cause of other diseases. The relation between smoking and hypertension still remains to be established [5]. Nevertheless, both systolic and diastolic pressures are increased after a single cigarette and, in the heavy smoker consuming two or three or more packages per day, arterial pressure may be increased most of the time [62]. In addition, even though blood pressure may be controlled equally in patients taking only diuretic or β-adrenergic blocking drugs, the smoker receiving the β-blocker (compared with the smoker receiving the diuretic) failed to have the same protection from death produced by stroke or coronary heart disease in the Medical Research Council and Australian Trials of Treatment of Mild Hypertension. Thus, as an important adjunctive lifestyle modification, cessation of smoking is certainly warranted [5].

Conclusion
Many risk factors for hypertension have been identified. Some, such as age, gender, and ethnicity are unmodifiable. However, a number of others may be modified and have been shown to reduce arterial pressure and the incidence of hypertension. These modifications include weight loss, low sodium diet, supplementation in potassium, alcohol moderation, and increased physical activity. Dietary fiber supplementation, vegetal protein supplementation, and coffee cessation may also be useful, but additional evidence is still needed to establish their efficacy in prevention of hypertension.

References and recommended reading
Papers of particular interest, published within the annual period of review, have been highlighted as:
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