Low Blood Pressure and Five-Year Mortality in a Stockholm Cohort of the Very Old: Possible Confounding by Cognitive Impairment and Other Factors

Zhenchao Guo, MD, Matti Viitanen, MD, PhD, and Bengt Winblad, MD, PhD

ABSTRACT

Objectives. Low blood pressure has often been reported to be related to excess mortality in people over the age of 75 years. This study examined whether other predictors may account for the association.

Methods. A community-based cohort of 1810 people who were aged 75 years and older was followed for 5 years.

Results. The relative risk of death was 1.39 (95% confidence interval [CI] = 1.11, 1.73) for people with systolic pressure lower than 130 mm Hg and 1.21 (95% CI = 1.02, 1.43) for those with diastolic pressure lower than 75 mm Hg, compared with corresponding reference groups, when all other variables were simultaneously considered in Cox proportional hazards models. The observed association was present mainly in subjects with at least two of the three conditions (cardiovascular disease, limitation in activities of daily living, or cognitive impairment). The effect of low diastolic pressure on mortality was also significant in those with only cognitive impairment.

Conclusions. Preexisting cardiovascular disease, limitation in activities of daily living, and, more important, cognitive impairment may be responsible for the association of low blood pressure with increased mortality in the very old in that they cause both reductions in blood pressure and excess deaths. (*Am J Public Health.* 1997;87:623–628)

Introduction

Low blood pressure (systolic and/or diastolic) has often been reported to be related to excess mortality in people over the age of 75 years.[1–7] However, most prior studies of blood pressure and mortality in the very old have not controlled for potential confounding by other predictors because of relatively small sample sizes. It has been argued that the observed association of low blood pressure and increased mortality may be due to the confounding effects of preexisting diseases and functional disability that result in both blood pressure reduction and excess mortality.[8] Several studies have explored these possibilities by excluding early deaths in the follow-up periods.[9,10] In a large community cohort aged 65 years and older, Glynn et al.[10] found that low blood pressure was related to excess deaths within the first 3 years of follow-up, while a positive linear relationship between blood pressure and mortality was present when the follow-up period was extended to 10.5 years and deaths in the first 3 years were excluded. However, these results may not necessarily be applicable to a very old population. In addition, since adjustment for several variables including some diseases and frailty did not modify the short-term relationship of low blood pressure with excess mortality, other confounders should be considered.[10]

Cognitive impairment is a risk factor for total mortality,[11–13] and in a previous study (unpublished manuscript) we found that cognitive function was positively related to blood pressure in people over the age of 75 years. In this case, it is quite possible that cognitive impairment would affect the relationship between blood pressure and mortality.

In this study we examine the relationship of blood pressure to 5-year all-cause mortality in a large community-based cohort of people aged 75 years and older, particularly taking into account preexisting cardiovascular disease, limitation in activities of daily living, and cognitive impairment.

Methods

Data for this study came from the Kungsholmen Project,[14] a large longitudinal study of aging and health initiated in 1987. The target population was all inhabitants of the Kungsholmen district of Stockholm who were aged 75 years or older on October 1, 1987. Of the eligible subjects, 1810 (77%) participated in the baseline survey between October 1987 and April 1989. Each baseline participant was followed until the date of death or until 5 years had passed. Survival data were obtained from Swedish national civil registration and regular contacts with the subjects or their relatives. The comparison of participants in the baseline interview with nonparticipants showed that nonparticipants were older, had a higher proportion of cardiovascular disease, and had shorter survival.

Arterial blood pressure was measured with a mercury sphygmomanometer with the subject in a sitting position after 5 minutes' rest. Korotkoff phases 1 and 5 were used for recording systolic and diastolic blood pressure, respectively. If

The authors are with the Stockholm Gerontology Research Center and Department of Geriatric Medicine, Karolinska Institute, Stockholm, Sweden.

Requests for reprints should be sent to Zhenchao Guo, MD, Stockholm Gerontology Research Center, Box 6401, S-113 82 Stockholm, Sweden.

This paper was accepted October 24, 1996.

TABLE 1—Baseline Characteristics and 5-Year Cumulative Mortality in a Community-Based Cohort of 1810 Swedish People Aged 75 Years and Older: The Kungsholmen Project

	Baseline n	Mortality, %
Age, y		
75–79	682	23.2
80–84	582	35.7
≥85	546	61.9
Sex		
Female	1378	37.0
Male	432	44.9
Education, y		
0–7	959	42.9
≥8[a]	851	34.4
Marital status		
Married	1346	39.8
Other[b]	464	36.2
Living place		
Home	1566	33.6
Institution	244	73.0
Antihypertensive drug use		
No	1029	36.2
Yes	781	42.5
Cancer		
No	1595	37.1
Yes	215	52.6
Heart disease		
No	1434	32.9
Yes	376	61.7
Stroke		
No	1657	36.8
Yes	153	61.4
Limitation in ADL		
None	896	27.7
One task	444	33.6
Two or more tasks	403	69.2
Missing value	67	41.8
Cognitive impairment		
No	1425	30.6
Mild	195	59.0
Moderate to severe	190	80.5
Systolic pressure, mm Hg		
<130	202	59.9
130–159	742	35.7
≥160	803	35.5
Missing value	63	52.4
Diastolic pressure, mm Hg		
<75	405	51.1
75–94	1100	35.5
≥95	242	30.2
Missing value	63	52.4

Note. ADL = activities of daily living.
[a]Included 15 people with missing value.
[b]Never-married, divorced, widow or widower.

the first reading was abnormal (systolic ≥160 or diastolic ≥95 mm Hg), two additional readings were taken. The mean of the second and third reading was used for analysis. Blood pressure was divided into three levels: low (systolic <130 or diastolic <75 mm Hg), middle (systolic 130–159 or diastolic 75–94 mm Hg), and high (systolic ≥160 or diastolic ≥95 mm Hg).

Cognitive function was assessed by the Mini-Mental State Examination (MMSE).[15] An MMSE score of less than 24 was considered to indicate cognitive impairment, with scores of 18 to 23 indicating mild impairment and scores of less than 18 indicating moderate to severe impairment. The subjects were classified as limited in activities of daily living if they were incontinent or required assistance to perform any of the following tasks: bathing, dressing, going to the toilet, transferring, and feeding.[16] An institution was defined as a nursing home, home for the elderly, long-term ward, or mental hospital. A medicine was considered to be used if it had been used in the 2 weeks before the baseline interview. Antihypertensive drugs included all medicines potentially used for lowering blood pressure, such as diuretics, beta-blockers, calcium channel antagonists, alpha-blockers, and angiotensin-converting enzyme inhibitors (Anatomical Therapeutic Chemical [ATC] classification system,[17] codes C02, C03, and C07). All interviewees were asked to show interviewers their medicines or prescription forms. If the subject was unable to provide reliable information, as assessed by response to the first few items of the questionnaire and to all items of the MMSE, a proxy respondent (relative, caregiver, or other) was required. Data on education, living place, marital status, drug use, and limitations in activities of daily living were obtained from proxies for 10% of the subjects.

Information on medical history for each participant was derived from the computerized inpatient register system that has covered all hospitals in the Stockholm area since 1969. We used cancer (*International Classification of Diseases, Eighth Revision* [ICD-8] codes 140–208, 230–239), heart disease (ICD-8 codes 390–429), and stroke (ICD-8 codes 430–438) as three covariables. These data may underestimate the prevalence or history of some diseases because some patients may never have been hospitalized, especially for mild cases of heart disease. A previous report showed that fewer than 10% of patients who suffer a stroke are not admitted to hospital in Sweden.[18]

Five-year cumulative mortality was calculated for each category of baseline variable and the significance of unadjusted differences in mortality between categories was determined by chi-square test. All significant variables were further assessed by a Cox proportional hazards model. The univariate Cox model included only one independent variable, and the dependent variable was survival time, which was the time from the date of baseline interview to the date of death or 60 months (5 years). A full-variable model was developed in which all significant variables from univariate models were included, but systolic and diastolic pressure were included separately. Nonsignificant variables in the full-variable model were then checked to find which variables might significantly contribute to the decrease in the effect of each of these variables. This was done by adding all other variables, one at a time, to the model that initially included one of these variables. Age, sex, and education were always the first variables added to the model. If the magnitude of the coefficient for a given variable decreased significantly, we considered that the added variable or variables might statistically explain the relationship of this variable with mortality found in the univariate model. To further examine the possible confounding of several important variables on the relationship between blood pressure and mortality, we developed separate multivariate Cox models. The effect of a potential risk factor for mortality was expressed as the relative risk (RR) of death; 95% confidence intervals that did not overlap 1.00 were considered significant. All calculations were performed with a standard statistical software package.[19]

TABLE 2—Relative Risks of Death Calculated from Univariate and Multivariate Cox Proportional Hazards Models: 5-Year Follow-Up of the Kungsholmen Project

Risk Factor	Univariate RR (95% CI)	Multivariate[a] RR (95% CI)
Age (1-year increase)	1.11 (1.10, 1.13)	1.08 (1.06, 1.09)
Male sex	1.29 (1.10, 1.53)	1.61 (1.36, 1.92)
Education (<8 vs ≥8 y)	1.33 (1.14, 1.54)	1.20 (1.02, 1.40)
Institutionalization	3.31 (2.79, 3.92)	1.01 (0.81, 1.27)
Antihypertensive drug use	1.24 (1.07, 1.44)	1.15 (0.98, 1.36)
Cancer	1.59 (1.30, 1.94)	1.40 (1.14, 1.71)
Heart disease	2.46 (2.10, 2.88)	1.82 (1.53, 2.16)
Stroke	2.05 (1.65, 2.55)	0.95 (0.76, 1.20)
ADL limitation		
One task	1.29 (1.05, 1.58)	1.29 (1.06, 1.59)
Two or more tasks	3.79 (3.19, 4.50)	2.15 (1.74, 2.66)
Missing value	1.68 (1.13, 2.48)	1.22 (0.81, 1.84)
Cognitive impairment		
Mild	2.45 (2.00, 3.01)	1.69 (1.36, 2.11)
Moderate to severe	4.82 (4.01, 5.81)	2.30 (1.78, 2.96)
Systolic pressure, mm Hg		
<130	2.05 (1.66, 2.55)	1.39 (1.11, 1.73)
130–159	1.00	1.00
≥160	0.96 (0.81, 1.13)	1.15 (0.97, 1.37)
Missing value	1.42 (0.95, 2.13)	0.86 (0.57, 1.30)
Diastolic pressure, mm Hg		
<75	1.66 (1.40, 1.97)	1.21 (1.02, 1.43)
75–94	1.00	1.00
≥95	0.81 (0.63, 1.03)	0.91 (0.71, 1.17)
Missing value	1.46 (0.98, 2.17)	0.81 (0.54, 1.22)

Note. RR = relative risk; CI = confidence interval; ADL = activities of daily living.
[a]Included age, sex, education, living place, antihypertensive drug use, cancer, heart disease, stroke, ADL status, cognitive function, and systolic pressure; the relative risk for diastolic pressure was adjusted for all other variables except systolic pressure.

Results

At baseline, the mean age was 83 years (range = 75 to 101 years). Of the participants, 11% had systolic pressure of less than 130 mm Hg, and 22% had diastolic pressure of less than 75 mm Hg; 44% had systolic pressure of 160 mm Hg or greater, and 13% had diastolic pressure of 95 mm Hg or greater. Cognitive impairment was present in 21%: 11% were mildly impaired and 10% were moderately or severely impaired. The prevalence of low blood pressure (both systolic pressure <130 mm Hg and diastolic pressure <75 mm Hg) was higher among those with cardiovascular disease, limitation in activities of daily living, or cognitive impairment. There was no significant difference in the prevalence of low blood pressure between those with and without antihypertensive drug use or cancer.

During the 5-year follow-up period, 704 participants (39%) died. Univariate chi-square tests showed that advanced age, male sex, lower education, institutionalization, cancer, heart disease, stroke, limitation in activities of daily living,

TABLE 3—Relative Risks of Death for Low Blood Pressure Calculated from Multivariate Cox Proportional Hazards Model: 5-Year Follow-Up of the Kungsholmen Project

	Systolic Pressure (<130 vs ≥130 mm Hg) RR (95% CI)	Diastolic Pressure (<75 vs ≥75 mm Hg) RR (95% CI)
Sex		
Female	1.55 (1.23, 1.96)	1.26 (1.04, 1.53)
Male	0.89 (0.57, 1.39)	1.21 (0.88, 1.67)
Antihypertensive drug use		
Yes	1.44 (1.04, 1.98)	1.13 (0.88, 1.45)
No	1.36 (1.04, 1.77)	1.39 (1.11, 1.73)
Cardiovascular disease		
Yes[a]	1.47 (1.10, 1.97)	1.19 (0.93, 1.52)
No	1.33 (0.99, 1.77)	1.29 (1.03, 1.62)
ADL limitation		
Yes	1.38 (1.09, 1.75)	1.32 (1.08, 1.63)
No[b]	1.30 (0.85, 1.98)	1.10 (0.83, 1.46)
Cognitive impairment		
Yes	1.50 (1.14, 1.98)	1.50 (1.17, 1.94)
No	1.25 (0.92, 1.72)	1.09 (0.88, 1.37)

Note. In each subpopulation, systolic and diastolic pressure were separately analyzed with all other variables. RR = relative risk; CI = confidence interval; ADL = activities of daily living.
[a]Included heart disease and stroke; n = 470.
[b]Included those with missing ADL value.

TABLE 4—Relative Risks of Death for Low Blood Pressure Calculated from Multivariate Cox Proportional Hazards Model in Five Subpopulations: 5-Year Follow-Up of the Kungsholmen Project

Subpopulation	No.	Systolic Pressure (<130 vs ≥130 mm Hg) RR (95% CI)	Diastolic Pressure (<75 vs ≥75 mm Hg) RR (95% CI)
No cardiovascular disease, ADL limitation, or cognitive impairment	668	0.91 (0.46, 1.79)	0.89 (0.58, 1.38)
Cardiovascular disease only	176	1.51 (0.68, 3.34)	0.69 (0.41, 1.19)
ADL limitation only	450	0.81 (0.44, 1.47)	1.35 (0.91, 2.01)
Cognitive impairment only	90	2.62 (0.92, 7.44)	2.95 (1.43, 6.10)
At least two of these three conditions	426	1.68 (1.31, 2.17)	1.38 (1.09, 1.74)

Note. The model was adjusted for age, sex, education, antihypertensive drug use, and cancer. RR = relative risk; CI = confidence interval; ADL = activities of daily living.

cognitive impairment, and low blood pressure were related to higher mortality (Table 1). Mortality among subjects with high blood pressure (both systolic pressure ≥160 mm Hg and diastolic pressure ≥95 mm Hg) was not significantly different from that among those with middle blood pressure levels (systolic pressure 130–159 mm Hg or diastolic pressure 75–94 mm Hg). Marital status was excluded from further analyses because it was unrelated to mortality in this population.

Univariate Cox models produced results similar to those from the chi-square tests (Table 2). A full-variable Cox model was fitted in which systolic and diastolic pressure were separately included with all other variables (Table 2). This procedure did not substantially change the relationship of low blood pressure to death, although the relationship became somewhat weak. Cognitive impairment, limitation in activities of daily living, increasing age, male sex, lower education, cancer, and heart disease remained significant predictors of mortality. The relative risks for institutionalization, antihypertensive drug use, and stroke were no longer significant in the full-variable model. Additional analyses indicated that controlling for cardiovascular disease, limitation in activities of daily living, and cognitive impairment was responsible for the reduction in the risk of death for institutionalization, and the prevalence of cardiovascular disease explained a substantial part of the univariate effect of antihypertensive drug use, while the decrease in the risk of death for stroke was largely due to the inclusion of activities-of-daily-living status in the model.

To make a further adjustment for several variables potentially affecting both blood pressure and mortality and to examine the independent effect of low blood pressure on mortality, we developed separate multivariate Cox regression models. Living place was not included in these models, as its effect was explained by other variables. Low blood pressure was compared with all other blood pressure groups (middle, high, and missing value), which were combined into one category. This approach can increase statistical power and will not result in overestimation of a given association. Table 3 lists adjusted relative risks of death for low blood pressure when the study population was categorized by sex, antihypertensive drug use, cardiovascular disease, limitation in activities of daily living, and cognitive impairment. When the study population was divided into two subpopulations by sex, the observed association of low blood pressure with increased mortality was seen mainly in women. Lower education was significantly related to increased mortality in men (adjusted RR = 1.60; P = .001) but not in women (adjusted RR = 1.04; P = .68). Separate models showed that the association of low blood pressure with increased mortality was independent of antihypertensive drug use. After other variables including cognitive impairment and limitation in activities of daily living were taken into account, the influence of cardiovascular disease on the relationship between low diastolic pressure and mortality was reduced. Separate models by cognitive impairment and limitation in activities of daily living showed a similar pattern; that is, the increased risk of death for both low systolic and low diastolic pressure was significant only among those with cognitive impairment or limitation in activities of daily living. Increasing age, male sex, cognitive impairment, and limitation in activities of daily living remained significant predictors of mortality in all separate models. Among those without cognitive impairment, stroke was related to an increased risk of death (adjusted RR = 1.37; P = .05).

To further assess the possible contribution of each of these three conditions (cardiovascular disease, limitation in activities of daily living, and cognitive impairment) to the effect of low blood pressure on mortality, we divided the whole population into five subpopulations by different combinations of these three conditions (Table 4). Increased mortality with low systolic pressure was significant only among those with at least two of these three conditions, and the effect of low diastolic pressure on mortality was also significant among those with cognitive impairment but without cardiovascular disease and limitation in activities of daily living. In the group without these three conditions, both low and high blood pressure, whether systolic or diastolic, were related to a slightly (not significant) decreased risk of death.

Discussion

Low Blood Pressure and Mortality

In this large community-based cohort of people aged 75 and older, there was a marked increase in 5-year all-cause mortality with low blood pressure. The relative risk of death was 2.05 ($P < .001$) for people with systolic pressure of less than 130 mm Hg compared with those with systolic pressure of 130 to 159 mm Hg, and 1.66 ($P < .001$) for people with diastolic pressure of less than 75 mm Hg compared with those with diastolic pressure of 75 to 94 mm Hg. When age, sex, education, living place, antihypertensive drug use, cancer, heart disease, stroke, activities-of-daily-living status, and cognitive function were simultaneously considered in the Cox regression models, the observed association was reduced but still significant (RR = 1.39, P = .004, for low systolic pressure; RR = 1.21, P = .037, for low diastolic pressure, in comparison with the corresponding reference groups). In agreement with other studies,[1–3] the association was seen mainly in women, although the opposite pattern has also been noted.[4–6]

At baseline, cardiovascular disease, limitation in activities of daily living, and cognitive impairment were related to low blood pressure. For further adjustment for these three variables, separate Cox regression models were developed. We found that the association of low blood pressure with increased mortality was present mainly in subjects with at least two of these three conditions, and the effect of low diastolic pressure was also significant among those with only cognitive impairment. A minor and nonsignificant decrease in the risk of death related to both low and high blood pressure was noted among those without any of these three conditions. Because of comorbidity of these conditions and a limited sample size, it is difficult to say to what extent each condition studied may contribute to the relationship between low blood pressure and mortality. However, cognitive impairment did appear to have an important influence on the relationship between low blood pressure and mortality. As the disease data were from hospital medical records, the effect of cardiovascular disease on mortality may be underestimated. It is very likely that cardiovascular disease, limitation in activities of daily living, and cognitive impairment are jointly responsible for the association of low blood pressure with increased mortality in that they cause both blood pressure reduction and excess death. However, our results do not exclude the possibility that the presence of low blood pressure may in itself increase the risk of death of persons with these three conditions. In particular, we cannot address the mechanism, suggested by other authors,[20,21] the possibility that low diastolic pressure may increase the risk of coronary death by lowering the coronary flow. The key to understanding the low blood pressure–mortality relationship is to know how these conditions change the blood pressure level. The presence of conditions such as cardiovascular disease may lower the usual level of blood pressure through treatment of the condition or changes in the patient's lifestyle, and the process of conditions such as cognitive impairment or Alzheimer's disease[22] may directly decrease the blood pressure level. Low blood pressure may just be a marker of these conditions, and inclusion of these conditions in the multivariate model may not solve the problem. This kind of bias caused by prevalent diseases in prospective studies has been noted by Joffres et al.,[23] who suggest that separate models by the presence of the prevalent disease should be fitted. Furthermore, low blood pressure can be the cause of cognitive impairment.[24] In this case, inclusion of cognitive impairment in the model would result in overadjustment of the effect of low blood pressure on mortality. It is difficult to disentangle these associations in this study, and additional studies are needed.

We did not find that high blood pressure, as compared with middle blood pressure levels, was related to increased death within 5 years of follow-up. In fact, compared with low blood pressure, high blood pressure is protective against mortality in the total population. Among those without cardiovascular disease, limitation in activities of daily living, and cognitive impairment, both low and high blood pressure were unrelated to excess mortality. However, our results with regard to the impact of high blood pressure on mortality need to be interpreted with caution. The prevalence of high blood pressure may be overestimated because of single recordings of blood pressure[25]; misclassification would underestimate the association. In addition, more than 40% of our subjects took antihypertensive drugs, which would lower blood pressure level and may decrease mortality, and this probably dilutes the effect of high blood pressure on mortality. Finally, a 5-year follow-up is relatively short; high blood pressure may be related to significantly increased mortality with longer observation.

Recent clinical trials have demonstrated that treatment of hypertension in the elderly is of significant benefit in total and cardiovascular mortality.[26,27] But the benefit is significantly reduced in the oldest age groups,[27] and few studies include sufficient numbers of very old adults; therefore, further clinical trials with big samples are needed in this age group. From a public health perspective, it is more important to first answer the question of whether high blood pressure, or hypertension, continues to be a risk factor for all-cause mortality, cardiovascular mortality, and incidence of cardiovascular disease in the very old.

Cognitive Impairment and Mortality

In our study, the relative risk of death was 1.69 ($P < .0001$) for mild cognitive impairment (defined by an MMSE score of 18–23) and 2.30 ($P < .0001$) for moderate to severe cognitive impairment (defined by an MMSE score of less than 18), adjusted for other variables. These results are similar to those of a recent study by Kelman and coworkers[12] using the same cognitive test, although their population was younger and had a higher prevalence of cognitive impairment than ours. Separate models showed that the effect was consistently significant in all subpopulations.

Cognitive impairment was defined by an MMSE score of less than 24, which is the common cutoff point for screening of dementia.[28] It is reasonable that cognitive impairment is related to increased mortality, since it predicts the presence of dementia with accepted sensitivity and specificity,[28] and people with dementia have shorter survival.[29,30] In addition, mild cognitive impairment may be a subclinical indicator of dementia[31] or other brain diseases[13] in some cases. Furthermore, cognitive impairment may be related to mortality indirectly, by increasing the risk of fractures[32] or as a manifestation of lower social status,[11] poor health (e.g., malnutrition),[33] or other illnesses or disturbances.[34]

To our knowledge, this is the first time that blood pressure and mortality have been analyzed according to subjects' cognitive status. Our results indicate that cognitive impairment is an important factor that may obscure the relationship of blood pressure to mortality. When the blood pressure–mortality relationship was examined separately in those with and without cognitive impairment, the predictive effect of low blood pressure (both systolic and diastolic) on mortality was influenced by the presence of cognitive impairment. Among those with cognitive impairment but without cardiovascular disease and limitation in activities of daily living, people with low diastolic pressure had a three times higher risk of dying within 5 years than those with higher diastolic pressure ($P = .004$), although the effect of low systolic pressure was not significant (RR = 2.62; $P = .07$) in this group. Further studies designed to examine the relationship of blood pressure to mortality in the very old should consider cognitive function as a covariable.

Functional Limitation and Other Predictors of Mortality

In accordance with previous findings,[33,35] our results showed that baseline limitation in activities of daily living was related to higher mortality. The relative risk of death was 1.29 ($P < .0001$) for one task limitation and 2.15 ($P < .0001$) for at least two task limitations, adjusted for other variables. Other predictors of mortality in this population are age, male sex, lower education, cancer, and heart disease. Separate models indicated that increased mortality with lower education was seen only in men. A substantial proportion of limitation in activities of daily living may result from stroke. Inclusion of activities-of-daily-living status in the model would lead to overadjustment of the effect of stroke. However, stroke remained a significant risk factor for mortality among those without cognitive impairment. Incomplete information on smoking, drinking, and body mass index prevented us from examining the effects of these variables, which may also affect the relationship between low blood pressure and mortality.

Conclusion

Preexisting cardiovascular disease, limitation in activities of daily living, and, more important, cognitive impairment may be responsible for the association of low blood pressure with increased mortality in that these conditions cause both blood pressure reductions and excess deaths, although the possibility of a biological relationship between low blood pressure and mortality cannot be excluded. Low blood pressure may not be harmful to people without these conditions, and caution should be used in lowering blood pressure levels below 130 mm Hg (systolic) or 75 mm Hg (diastolic) in those with these conditions. Further studies will be required to document the risk factors for low blood pressure and to identify specific causes of death that may be related to low blood pressure or conditions such as cognitive impairment and limitation in activities of daily living. Our results also emphasize the need for more detailed evaluation of the malignancy of high blood pressure or hypertension in the very old. ☐

Acknowledgments

This study was supported by the Swedish Medical Research Council, the Swedish Council for Social Research, the Swedish Municipal Pension Institute, the Torsten & Ragnar Söderbergs Foundation, and the SHMF Foundation.

We thank the workers of the Kungsholmen Project for their collaboration in collecting and managing data and Phillippa Wills for her assistance in the preparation of this manuscript.

References

1. Rajala S, Haavisto M, Heikinheimo R, Mattila K. Blood pressure and mortality in the very old. *Lancet.* 1983;2:520–521.
2. Mattila K, Haavisto M, Rajala S, Heikinheimo R. Blood pressure and five year survival in the very old. *BMJ.* 1988;296: 887–889.
3. Sørensen KH, Hilden T. Increased total mortality and decreased functional capacity are associated with low systolic blood pressure among elderly women. *Scand J Prim Health Care.* 1988;6:105–110.
4. Langer RD, Ganiats TG, Barrett-Connor E. Paradoxical survival of elderly men with high blood pressure. *BMJ.* 1989;298:1356–1358.
5. Langer RD, Ganiats TG, Barrett-Connor E. Factors associated with paradoxical survival at higher blood pressures in the very old. *Am J Epidemiol.* 1991;134:29–38.
6. Langer RD, Criqui MH, Barrett-Connor EL, Klauber MR, Ganiats TG. Blood pressure change and survival after age 75. *Hypertension.* 1993;22:551–559.
7. Bulpitt CJ, Fletcher AE. Prognostic significance of blood pressure in the very old: implications for the treatment decision. *Drugs Aging.* 1994;5:184–191.
8. Taylor JO, Cornoni-Huntley J, Curb JD, et al. Blood pressure and mortality risk in the elderly. *Am J Epidemiol.* 1991;134:489–501.
9. Vatten LJ, Holmen J, Krüger Ø, Forsén L, Tverdal A. Low blood pressure and mortality in the elderly: a 6-year follow-up of 18,022 Norwegian men and women age 65 years and older. *Epidemiology.* 1995;6:70–73.
10. Glynn RJ, Field TS, Rosner B, Hebert PR, Taylor JO, Hennekens CH. Evidence for a positive linear relation between blood pressure and mortality in elderly people. *Lancet.* 1995;345:825–829.
11. Liu IY, LaCroix AZ, White LR, Kittner SJ, Wolf PA. Cognitive impairment and mortality: a study of possible confounders. *Am J Epidemiol.* 1990;132:136–143.
12. Kelman HR, Thomas C, Kennedy GJ, Cheng J. Cognitive impairment and mortality in older community residents. *Am J Public Health.* 1994;84:1255–1260.
13. Swan GE, Carmelli D, LaRue A. Performance of the Digit Symbol Substitution Test and 5-year mortality in the Western Collaborative Group Study. *Am J Epidemiol.* 1995;141:32–40.
14. Fratiglioni L, Viitanen M, Bäckman L, Sandman PO, Winblad B. Occurrence of dementia in advanced age: the study design of the Kungsholmen Project. *Neuroepidemiology.* 1992;11(suppl 1):29–36.
15. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res.* 1975;12:189–198.
16. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The Index of ADL: a standardized measure of biological and psychological function. *JAMA.* 1963;185:914–919.
17. *Guidelines for ATC Classification.* Uppsala, Sweden: WHO Collaborating Centre for Drug Statistics Methodology, Norway and Nordic Council on Medicines; 1990.
18. Alfredsson L, von Arbin M, de Faire U. Mortality from and incidence of stroke in Stockholm. *BMJ.* 1986;292:1299–1303.
19. *SPSS Advanced Statistics 6.1.* Chicago, Ill: SPSS Inc; 1994.
20. Cruickshank JM. Coronary flow reserve and the J curve relation between diastolic blood pressure and myocardial infarction. *BMJ.* 1988;297:1227–1230.
21. D'Agostino RB, Belanger AJ, Kannel WB, Cruickshank JM. Relation of low diastolic blood pressure to coronary heart disease death in presence of myocardial infarction: the Framingham study. *BMJ.* 1991;303: 385–389.
22. Burke WJ, Coronado PG, Schmitt CA, Gillespie KM, Chung HD. Blood pressure regulation in Alzheimer's disease. *J Auton Nerv Syst.* 1994;48:65–71.
23. Joffres MR, Maclean CJ, Reed DM, Yano K, Benfante R. Potential bias due to prevalent diseases in prospective studies. *Int J Epidemiol.* 1990;19:459–465.
24. Román GC. Senile dementia of the Binswanger type. A vascular form of dementia in the elderly. *JAMA.* 1987;258: 1782–1788.
25. Pickering TG. Blood pressure measurement and detection of hypertension. *Lancet.* 1994;344:31–35.
26. Mulrow CD, Cornell JA, Herrera CR, Kadri A, Farnett L, Aguilar C. Hypertension in the elderly: implications and generalizability of randomized trials. *JAMA.* 1994;272:1932–1938.
27. Insua JT, Sacks HS, Lau TS, et al. Drug treatment of hypertension in the elderly: a meta-analysis. *Ann Intern Med.* 1994;121: 355–362.
28. Tombaugh TN, McIntyre NJ. The Mini-Mental State Examination: a comprehensive review. *J Am Geriatr Soc.* 1992;40: 922–935.
29. Evans DA, Smith LA, Scherr PA, Albert MS, Funkenstein HH, Hebert LE. Risk of death from Alzheimer's disease in a community population of older persons. *Am J Epidemiol.* 1991;134:403–412.
30. Katzman R, Hill LR, Yu ESH, et al. The malignancy of dementia: predictors of mortality in clinically diagnosed dementia in a population survey of Shanghai, China. *Arch Neurol.* 1994;51:1220–1225.
31. Flicker C, Ferris SH, Reisberg B. Mild cognitive impairment in the elderly: predictors of dementia. *Neurology.* 1991;41:1006–1009.
32. Buchner DM, Larson EB. Falls and fractures in patients with Alzheimer-type dementia. *JAMA.* 1987;257:1492–1495.
33. Salive ME, Satterfield S, Ostfeld AM, Wallace RB, Havlik RJ. Disability and cognitive impairment are risk factors for pneumonia-related mortality in older adults. *Public Health Rep.* 1993;108:314–322.
34. Colsher PL, Wallace RB. Epidemiologic considerations in studies of cognitive function in the elderly: methodology and nondementing acquired dysfunction. *Epidemiol Rev.* 1991;13:1–27.
35. Harris T, Kovar MG, Suzman R, Kleinman JC, Feldman JJ. Longitudinal study of physical ability in the oldest-old. *Am J Public Health.* 1989;79:698–702.