A comparison of the twenty-four-hour blood pressure profile in normotensive and hypertensive subjects

John Cox, Kevin O'Malley, Neil Atkins and Eoin O'Brien

The aim of this study was to assess the relationship between blood pressure measured conventionally ('conventional' pressure) and 24 h ambulatory blood pressure measured with the SpaceLabs 90202 recorder, in a control population with normal blood pressure, and in patients with hypertension. Reference values for 24 h ambulatory blood pressure had been determined previously in a control population of 776 healthy bank employees (396 men and 380 women), aged 17–80 years, and were compared with those from a clinic population which comprised 805 patients referred to a blood pressure clinic for evaluation of hypertension. The clinic population was divided into two groups: 'normotensive' patients, whose conventional blood pressure was $<160/90$ mmHg ($n = 168$), and 'hypertensive' patients, whose conventional blood pressure was $\geq 160/90$ mmHg ($n = 637$).

The clinic population had higher conventional (156/87 versus 119/76 mmHg), daytime (147/90 versus 125/79 mmHg) and night-time (129/75 versus 106/61 mmHg) ambulatory pressures compared with the control population. The clinic 'hypertensive' patients had higher conventional (175/97 versus 136/77 mmHg), daytime (153/93 versus 140/87 mmHg) and night-time (133/78 versus 124/72 mmHg) ambulatory pressures than the clinic normotensive population. Daytime ambulatory pressure was higher than conventional pressure (125/79 versus 119/76 mmHg) in the control population and in the clinic normotensive population (140/87 versus 136/77 mmHg). However, this relationship was reversed in the clinic hypertensive patients (153/93 versus 175/97 mmHg).

It is concluded that while conventionally measured blood pressure tends to be lower than ambulatory daytime pressure in normotensive populations, this relationship is reversed in patients with hypertension.

Journal of Hypertension 1991, **9** (suppl 1):S3–S6

Keywords: Ambulatory blood pressure, normotensive subjects, hypertensive subjects.

Introduction

Ambulatory blood pressure monitoring is rapidly gaining acceptance as a useful procedure in the clinical management of hypertension [1,2], in the assessment of antihypertensive drugs [3] and as a means of predicting outcome in hypertension [4]. Ambulatory blood pressure monitoring also provides an assessment of blood pressure behaviour with respect to time in the patient's environment and is likely to result in reappraisal of the clinical management of hypertension, which at present, is based on conventional measurement techniques [5]. With the development of devices capable of accurately measuring 24-h blood pressure non-invasively, the use of ambulatory blood pressure monitoring in clinical practice has increased considerably in the last decade [2,6]. Surprisingly, the application of the technique has grown in the absence of reference values for 24-h ambulatory blood pressure. Recently, we performed a population study in healthy bank employees and compared these reference values with 24-h ambulatory blood pressures in hypertensive subjects [7].

Subjects and methods

All hypertensive patients referred to the blood pressure clinic at Beaumont Hospital undergo 24-h ambulatory

From the Blood Pressure Unit, Beaumont Hospital, and the Department of Clinical Pharmacology, Royal College of Surgeons in Ireland, Dublin, Ireland.

Sponsorship: This work was supported by grants from the Charitable Infirmary Charitable Trust, the Royal College of Surgeons in Ireland, the Irish Heart Foundation and ICI Pharmaceuticals.

Requests for reprints to: Dr Eoin O'Brien, Blood Pressure Unit, Beaumont Hospital, Dublin 9, Ireland.

blood pressure monitoring, and the data are stored on a computer database.

Control population

Conventional blood pressure measurement and 24-h ambulatory blood pressure monitoring were performed in 776 employees of the Allied Irish Bank. The measurements were used as reference values for data from clinic patients. The subjects for the study were recruited by the Medical Centre of the Allied Irish Bank in Dublin and comprised bank employees and their spouses.

Clinic population

A total of 805 patients, who had been referred to our clinic for an assessment of possible hypertension, underwent conventional and 24-h ambulatory blood pressure measurement. The clinic population was divided into two groups, normotensive patients, whose clinic blood pressure was $<160/90$ mmHg ($n = 168$), and hypertensive patients, whose blood pressure was $\geq 160/90$ mmHg ($n = 637$).

Blood pressure measurement and data analysis

Conventional blood pressure measurements were taken in the sitting position by a doctor or nurse using a mercury sphygmomanometer, according to the recommendations of the British Hypertension Society [8]. Twenty-four-hour ambulatory blood pressure monitoring was performed using the SpaceLabs 90202, which has been shown to be accurate [9]. Most subjects were fitted with the recorder between 0900 and 1300 h; it was programmed to deflate in steps of 4 mmHg at 30-min intervals for 24 h. The 24-h interval was divided into daytime and night-time periods, daytime being defined as 1000 to 1950 h and night-time as 0100 to 0559 h. The 24-h recordings were not edited, to avoid the introduction of bias. Hourly, average pressures were computed, using the mean of all readings taken in that interval (e.g. the hourly average for 1000 h was calculated using all readings taken from 1000 to 1059 h), and the sum of these hourly averages divided by 24 was used to calculate the mean 24-h ambulatory pressure. The means (± s.d.) of daytime, night-time and 24-h systolic and diastolic blood pressure were calculated for men and women in the age groups 17–49 years and 50–80 years. The analysis was performed using the SAS software package [10].

Results

Control population

Conventional and 24-h ambulatory blood pressure measurements were available for analysis in 776 subjects (396 men and 380 women), aged 17–80 years (mean age 36 ± 11 years). There were 332 men and 335 women in the 17–49 year age group, and 64 men and 45 women in the 50–80 year age group [7]. The means (± s.d.) of the clinic and the daytime, night-time and 24-h ambulatory blood pressures for men and women in both age groups are shown in Table 1.

Control versus clinic patients

A total of 805 measurements (160 normotensive and 637 hypertensive) were available for comparison with the control group. The means (± s.d.) of the clinic, daytime, night-time and 24-h ambulatory blood pressure measurements for men and women in both age groups are shown in Table 2.

Both the conventional and the ambulatory blood pressures were higher in the clinic population than in the control population. Similarly, these pressures were higher in the hypertensive than in the normotensive clinic group. Men had higher pressures than women in both the control population and the normotensive clinic group, but this sex difference was not apparent in the hypertensive clinic group. While conventional systolic pressure and ambulatory measurements were higher in older men and women in the control population, this effect was confined to the conventional measurements in the hypertensive clinic patients, and was not apparent in the normotensive clinic group.

In the control group, daytime ambulatory blood pressures were higher than conventional pressures for the population as a whole, though within the age and sex groups any differences were small. In the clinic population, however, daytime ambulatory pressures were lower than conventional measurements for the group as

Table 1. Mean (± s.d.) clinic and 24-h ambulatory blood pressures in a normotensive control population, grouped according to age and sex.

	Men		Women		
	17–49 years (n = 332)	50–80 years (n = 64)	17–49 years (n = 335)	50–80 years (n = 45)	Total (n = 776)
Clinic measurements					
Systolic blood pressure (mmHg)	122 ± 14	134 ± 17	112 ± 16	131 ± 27	119 ± 18
Diastolic blood pressure (mmHg)	77 ± 10	85 ± 12	71 ± 9	81 ± 13	76 ± 11
Ambulatory measurements					
Daytime systolic blood pressure (mmHg)	129 ± 9	132 ± 12	118 ± 7	129 ± 15	125 ± 11
Daytime diastolic blood pressure (mmHg)	81 ± 9	85 ± 9	75 ± 6	79 ± 8	79 ± 7
Night-time systolic blood pressure (mmHg)	109 ± 10	112 ± 12	102 ± 8	109 ± 13	106 ± 11
Night-time diastolic blood pressure (mmHg)	62 ± 7	68 ± 9	58 ± 7	64 ± 7	61 ± 8
24-h systolic blood pressure (mmHg)	123 ± 10	125 ± 12	112 ± 8	121 ± 15	118 ± 11
24-h diastolic blood pressure (mmHg)	74 ± 6	79 ± 9	69 ± 6	74 ± 8	72 ± 10

Table 2. Mean (± s.d.) clinic and 24-h ambulatory blood pressure in a clinic population grouped according to age and sex.

	Normotensives					Hypertensives				
	Men		Women			Men		Women		
	17–49 years (n = 53)	50–80 years (n = 43)	17–49 years (n = 31)	50–80 years (n = 41)	Total (n = 168)	17–49 years (n = 113)	50–80 years (n = 191)	17–49 years (n = 215)	50–80 years (n = 118)	Total (n = 637)
Clinic measurements										
SBP	134 ± 14	136 ± 16	137 ± 12	137 ± 18	136 ± 15	161 ± 22	180 ± 22	171 ± 19	181 ± 31	175 ± 26
DBP	78 ± 7	77 ± 9	78 ± 7	77 ± 9	77 ± 8	97 ± 12	896 ± 13	96 ± 14	96 ± 14	97 ± 14
Ambulatory measurements										
Daytime SBP	144 ± 15	140 ± 15	135 ± 13	139 ± 19	140 ± 16	150 ± 17	154 ± 19	150 ± 16	155 ± 20	153 ± 19
Daytime DBP	89 ± 11	88 ± 12	87 ± 11	82 ± 10	87 ± 11	97 ± 11	93 ± 12	96 ± 13	89 ± 12	93 ± 13
Night-time SBP	123 ± 14	124 ± 19	117 ± 14	129 ± 22	124 ± 18	127 ± 18	138 ± 20	127 ± 18	136 ± 22	133 ± 20
Night-time DBP	71 ± 10	73 ± 19	69 ± 13	73 ± 12	72 ± 12	78 ± 13	80 ± 13	77 ± 13	75 ± 13	78 ± 13
24-h SBP	137 ± 14	135 ± 16	128 ± 12	136 ± 18	134 ± 15	142 ± 16	149 ± 18	142 ± 16	149 ± 19	146 ± 18
24-h DBP	83 ± 10	83 ± 11	80 ± 12	79 ± 10	82 ± 11	90 ± 11	89 ± 11	89 ± 12	85 ± 12	88 ± 12

Blood pressure given in mmHg. SBP, sytolic blood pressure; DBP, diastolic blood pressure.

a whole; in the hypertensive group this difference was substantial for systolic pressure, with daytime pressures being 22/4 mmHg lower than conventional pressures.

Discussion

Comparison of ambulatory blood pressure levels and 24-h profiles between hypertensive patients and normal controls has been hampered by the absence of reference values for 24-h blood pressure. A number of studies are now being performed to provide much needed reference values. In this study, 24-h ambulatory blood pressure measurements obtained in a control group of healthy bank employees were compared with those from clinic hypertensive patients, and the relationship between conventional measurements and daytime ambulatory measurements was examined in the two groups.

In the hypertensive clinic group, blood pressure was higher with conventional measurements compared with daytime ambulatory measurements, in contrast to the control population and the normotensive clinic group, each of which tended to have higher pressures with ambulatory measurement than with conventional measurement. This discrepancy was greatest for systolic pressure in older men. Moreover, the discrepancy increased with age in the hypertensive clinic group, particularly in the men. In men, there was a difference of 11/2 mmHg between the two methods of measurement in the younger age group, which increased to 26/3 mmHg in the older age group; in women, a difference of 21/3 mmHg was increased to 26/6 mmHg. Surprisingly, there was no marked difference with age or sex in the normotensive clinic group. The differences between conventional and ambulatory measurement are greater for systolic than diastolic pressure, and these differences are greater in hypertensive than in normotensive subjects.

A number of studies have shown that ambulatory blood pressure monitoring gives lower readings than conventional office or home measurement in hypertensive patients [2,6,11–13]. In a study comparing the differences between conventional and ambulatory measurement in normotensive subjects and hypertensive patients, the conventional measurement was higher than the ambulatory measurement in the hypertensive patients than in the control group [14].

It is apparent from these results that clinic normotensives are quite different from the normotensive control population, and clearly, patients referred for investigation or management of elevated blood pressure, even if they are subsequently shown to have normal pressure, cannot be used to characterize normal values for ambulatory blood pressure.

The most interesting finding in this analysis was the relationship between conventional measurement and daytime ambulatory blood pressure. The fact that daytime ambulatory pressures were higher than conventionally measured pressures in the normotensive control subjects and in the clinic normotensives, and that this relationship was reversed in clinic hypertensive patients, has important implications for clinical practice. At present, hypertension is diagnosed according to the level of blood pressure measured by the conventional technique rather than by ambulatory measurement. Many patients who have an exaggerated blood pressure response in the clinic may therefore be misdiagnosed as hypertensive or the severity of their hypertension may be exaggerated [15].

Further, the alteration in the relationship between conventional measurements and daytime ambulatory measurements may be one of the earliest clinical indications of an abnormality in blood pressure control; the reversal of the relationship may mark the transition from a normotensive to hypertensive state. While it is only a matter of time before 24-h ambulatory blood pressure monitoring becomes integral to the diagnosis of hypertension, it is important that the technique is not viewed in isolation

from conventional measurements, as both techniques are clearly complementary to each other.

References

1. PICKERING TG, HARSHFIELD GA, KLEINERT HD, BLANK S, LARAGH JH: Blood pressure during normal daily activities, sleep, and exercise. Comparison of values in normal and hypertensive subjects. *JAMA* 1982, 247:992–996.
2. MANCIA G: Clinical use of ambulatory blood pressure monitoring. *Am J Hypertens* 1989, 2 (suppl):50S–54S.
3. O'BRIEN E, COX J, O'MALLEY K: Editorial review: Ambulatory blood pressure measurement in the evaluation of blood pressure lowering drugs. *J Hypertens* 1989, 7:243–247.
4. PERLOFF D, SOKOLOW M, COWAN RM, JUSTER RP: Prognostic value of ambulatory blood pressure measurements: further analysis. *J Hypertens* 1989, 7 (suppl 3):S3–S10.
5. O'BRIEN E, O'MALLEY K: Overdiagnosing hypertension: a fifth of patients with borderline hypertension may be treated unnecessarily. *Br Med J* 1988, 297:1211–1212.
6. WHITE WB: Assessment of patients with office hypertension by 24-hour noninvasive ambulatory blood pressure monitoring. *Arch Intern Med* 1986, 146:2196–2199.
7. O'BRIEN E, MURPHY J, TYNDALL A, ATKINS N, MCCARTHY G, O'MALLEY K: 24-Hour ambulatory blood pressure in normotensive subjects. *Am J Hypertens* 1990, 3:351–352.
8. PETRIE JC, O'BRIEN ET, LITTLER WA, DE SWIET M: Recommendations on blood pressure measurement: British Hypertension Society. *Br Med J* 1986, 293:611–615.
9. O'BRIEN E, SHERIDAN J, BROWNE T, CONROY R, O'MALLEY K: Validation of the SpaceLabs 90202 ambulatory blood pressure recorder. *J Hypertens* 1989, 7 (suppl 6):S388–S389.
10. STRATEGIC APPLICATIONS SOFTWARE INSTITUTE: *SAS Users' Guide: Basics.* Cary, North Carolina: SAS Institute, 1982.
11. KENNY RA, BRENNAN M, O'MALLEY K, O'BRIEN E: Blood pressure measurements in borderline hypertension. *J Hypertens* 1987, 5 (suppl 5):S483–S485.
12. O'BRIEN E, FITZGERALD D, O'MALLEY K: Comparison of clinic, home and ambulatory blood pressure measurement. *J Ambulatory Monit* 1988, 1:285–291.
13. PICKERING TG, JAMES GD: Some implications of the differences between home, clinic and ambulatory blood pressure in normotensive and hypertensive patients. *J Hypertens* 1989, 7 (suppl 3):S65–S72.
14. HARSHFIELD GA, PICKERING TG, JAMES GD, BLANK SG: Blood pressure variability and reactivity in the natural environment. In *Blood Pressure Measurements: New Techniques in Automatic and 24-Hour Indirect Monitoring Pressure Measurements* edited by Meyer-Sabellek W, Anlauf M, Gotzen R, Steinfield L. Darmstadt: Steinkopff/Springer, 1990, pp 241–251.
15. PICKERING TG, JAMES GD, BODDIE C, HARSHFIELD GA, BLANK S, LARAGH JH: How common is white coat hypertension? *JAMA* 1988, 259:225–228.

Discussion

M. Ishii (Japan): We have demonstrated that sympathetic nervous activity is enhanced in elderly patients with essential hypertension, and that circadian variation in blood pressure is mainly modulated by sympathetic nervous activity. Did Dr O'Brien find any effects of ageing in the difference between conventional and ambulatory blood pressures?

E. O'Brien (Ireland): Yes, we did. I did not show these very interesting data. The phenomenon of systolic hypertension in the ageing population, which includes many people with isolated systolic hypertension, was demonstrated quite clearly by the conventional blood pressure measurement. However, isolated systolic blood pressure elevation disappears to a large extent with ambulatory daytime measurements. In other words, the phenomenon of systolic hypertension, the existence of which is clearly shown with conventional measurement, appears to be a matter of circumstance, rather than a persistent reality throughout the 24 h. It seems to occur mostly in the presence of the physician in the conventional blood pressure setting.

J. Staessen (Belgium): Were the bands of normality on some of Dr O'Brien's slides computed on hourly means or on single measurements? Secondly, is it appropriate to plot single measurements on bands if the bands are computed on hourly means?

E. O'Brien (Ireland): The bands of normality were computed on hourly means. I take the point that it may not be valid to plot individual measurements in a different manner, and that hourly means would be better theoretically, though little better in practice.

K. Abe (Japan): My co-worker, Dr Imai, has done a cross-sectional survey of clinic, home and ambulatory blood pressures in a rural community of northern Japan. He measured ambulatory blood pressure in about 700 subjects. According to his data, the average 24-h ambulatory blood pressure gradually increased with age. Six hundred subjects were normotensive by clinic blood pressure, whereas 95% were normotensive by daytime ambulatory blood pressure.

E. O'Brien (Ireland): I am familiar with Dr Imai's and your work. It is an interesting population study, and similar to ours. Dr Staessen will be returning to this point later, so I will not comment further.

P. Verdecchia (Italy): Dr O'Brien used the 95th percentile to define the upper limit of normality. I have also seen the 95th percentile used in the literature. Can he explain the reason for this variation?

E. O'Brien (Ireland): It is difficult to decide whether to use the 90th and the 10th or the 95th and the 5th percentiles. I showed the 95th, but we do have the figures for the 90th. It depends how liberal we want to be in relation to reference values, and also whether plus or minus two standard deviations should be used as an alternative. I do not think a clear decision has yet been made about the best way of expressing normality.

T. Pickering (USA): I hope that, when the data are published, these different measures will be included so that data from different studies can be compared directly and the best definition decided.