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Comparison of clinic, home and ambulatory blood pressure measurement

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Twenty untreated patients with diastolic blood pressure between 90 and 110 mmHg had their blood pressures measured with a mercury sphygmomanometer at fortnightly intervals over a 6-week period during which time one 12-hour ambulatory blood pressure (ABP) measurement was also recorded. This was followed by a 2-month period of home recording of blood pressure (HBP) during which fortnightly measurements were made at the clinic (CBP) together with two 12-hour ABP measurements. During a further 4-week period fortnightly clinic measurements were made with one final assessment of ABP. Of the three methods of blood pressure assessment, ABP gave statistically significant lower systolic blood pressures than either HBP ($p < 0.001$) or CBP ($p < 0.001$). Similar trends were observed for diastolic pressure but were not significant. The relationship between the three measurement systems was highly variable, though differences between home and clinic recordings, and between ambulatory and clinic recordings, were significantly correlated both for systolic and diastolic pressures. Home recording as judged by clinic and ambulatory blood pressure measurements did not have a blood pressure lowering effect.

Keywords: Home recording; clinic blood pressure; ambulatory blood pressure; Remler.

Introduction

Ambulatory blood pressure (ABP) may be a better predictor of end-organ damage and therefore of severity of disease than clinic-recorded blood pressure (CBP) in hypertensive subjects [1]. However, the automated portable blood pressure recorders on which these studies are based are expensive and not widely available [2]. Home recording of blood pressure (HBP) is a practical alternative and has been advocated as a method of assessing blood pressure outside the clinic [3, 4]. Most studies have shown that patients [5] or their relatives [6] achieve a degree of accuracy comparable with trained medical staff after only a short period of training. It has been suggested that HBP may have a blood pressure lowering effect in hypertensive subjects [7–9] but this observation has been based on clinic recordings. In this study CBP and HBP recordings are compared with ABP recordings obtained with a portable device which allows blood pressure measurement during normal daily activities. In addition the effect of home recording by the patient on both clinic and ambulatory blood pressure behaviour is assessed.

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Methods

Study group

Nineteen patients with untreated essential hypertension with diastolic blood pressures between 90 and 110 mmHg on two successive clinic visits had clinic pressure recorded at 2-weekly intervals over a 6-week period and ambulatory blood pressure was recorded non-invasively during waking hours using a Remler M2000 semi-automatic portable blood pressure recorder on one day between the second and third clinic visits. This was followed by HBP recording for 8 weeks during which clinic pressures were recorded every 2 weeks, and ambulatory recordings were repeated at 4 weeks and 8 weeks. Following the period of home recording patients attended the clinic for a further 4 weeks for clinic measurements at 2-weekly intervals and ambulatory recording prior to the last clinic visit. In all cases phase V of the Korotkov sounds was taken as the diastolic end-point.

Clinic blood pressure

This was measured in the sitting position on the left arm after 3 min rest with standard mercury sphygmomanometer.

Home recording

Groups of two to four patients attended separate training sessions consisting of a practical demonstration in blood pressure measurement and individual training by medical staff as previously described [6]. To facilitate easy home use new aneroid sphygmomanometers, with a cuff containing the stethoscope head that could be applied readily to the arm with one hand, were used. Following training, patients practised self-recording of blood pressure both on themselves and other patients for 20 min. At the end of this period their accuracy was assessed by medical staff using a stethoscope with two sets of earpieces. Patients were requested to practise at home, and returned after 1 week for assessment. Any questions or problems were discussed, following which an assessment of accuracy was made by medical staff with a dual stethoscope.

Accuracy was defined as a deviation of not more than 5 mmHg in the mean of two consecutive recordings of systolic and diastolic blood pressures between the patient and trained medical staff. If the patients failed to achieve the required degree of accuracy a further period of training followed and patients were reassessed after 1 week.

Patients measured their blood pressure twice daily after sitting quietly with the arm supported for 3 min, one recording being made between 0700 h and 1000 h and one between 1700 h and 2000 h. Blood pressure measurements were recorded in a notebook. At the end of the period of home recording the accuracy of the patient's sphygmomanometers was assessed against a standard mercury sphygmomanometer. No further attempt was made during the study to assess patient accuracy unless patients admitted to having problems with the recording technique.

Ambulatory blood pressure

This was measured with a portable non-invasive semi-automated blood pressure recorder, the Remler M2000 which we have shown to be accurate [10], and the recordings of which are reproducible [11]. The magnetic tape was decoded by auscultating each tape to minimize inaccuracy in interpretation. Patients attended the hospital at 0900 h to have the recorder fitted and recorded their blood pressure thereafter at 30-min intervals until they retired to bed. Home recordings were not attempted on the day of ambulatory measurement.

Data analysis

The four clinic pressures during home recording were compared with the two clinic pressures immediately preceding and the two clinic pressures following home recordings. Similarly, the two ambulatory recordings (mean of all recordings in the day) during the home recording period were compared with the ambulatory recording immediately preceding and that following home recording. The first day of ambulatory recording was not included in the analysis as previous studies have suggested that recordings on subsequent days tend to be lower [12, 13]. For comparison of methods, the mean of each 2 weeks of home recording (four measurements) was compared with the corresponding clinic (four measurements) and mean ambulatory blood pressures (two measurements). Comparison of multiple means was by two-way analysis of variance with Scheffe's correction for multiple comparisons where appropriate [14]. When Scheffe's correction was used, a probability level of 10% was considered to be significant.

Results

Of the 20 patients recruited for the study one patient failed to return to the clinic and one had a marked rise in clinic and ambulatory blood pressure during the home recording period which was not detectable by her own blood pressure determinations, and as neither of these patients completed the study their data are not included. Another patient required treatment after completion of the home recording period, but prior to her final clinic visit, because of an excessive rise in home and clinic blood pressure, and is included in the analysis. The mean age (± SEM) of the remaining 18 patients was 43.9 ± 2.1 with a range of 29 to 60 years. All patients achieved the required degree of accuracy in self-recording of blood pressure.

Home-recorded blood pressures were less than clinic pressures although this was significant only for systolic blood pressure (table 1, figure 1). Similarly, comparison of ambulatory recordings with clinic and home recordings during the home-recording period showed that ambulatory systolic, but not diastolic, recordings were less than both home and clinic blood pressures. However, the relationships between home, clinic and ambulatory recordings were highly variable, particularly for systolic pressure recordings (table 2). Differences between home and clinic recordings, and between ambulatory and clinic recordings, were significantly correlated both for systolic and diastolic pressures.

Home–clinic differences tended to decrease with age, though this was significant

Table 1. Comparison of home (HBP, four 2-weekly intervals), clinic (CBP, four 2-weekly visits), and ambulatory (ABP, 2 days) blood pressures during the home recording period in 18 patients

	HBP	CBP	ABP
Systolic blood pressure			
Mean ± SEM	153.5 ± 3.5	160.0 ± 3.9	147.9 ± 3.2
Mean difference		6.5 ± 3.1*	12.1 ± 3.8*
Mean HBP–CBP difference		5.4 ± 3.3*	
Diastolic blood pressure			
Mean ± SEM	93.6 ± 2.6	95.7 ± 2.6	96.8 ± 2.8
Mean difference		2.1 ± 1.6	1.1 ± 1.5
Mean HBP–CBP difference		3.2 ± 1.6	

* $p < 0.001$.

only for diastolic blood pressure. During the home-recording phase no change occurred in systolic or diastolic blood pressure recorded in the clinic. Similarly, there was no change in ambulatory blood pressure during this phase when compared with the ambulatory recordings preceding and following the home-recording period (figure 1).

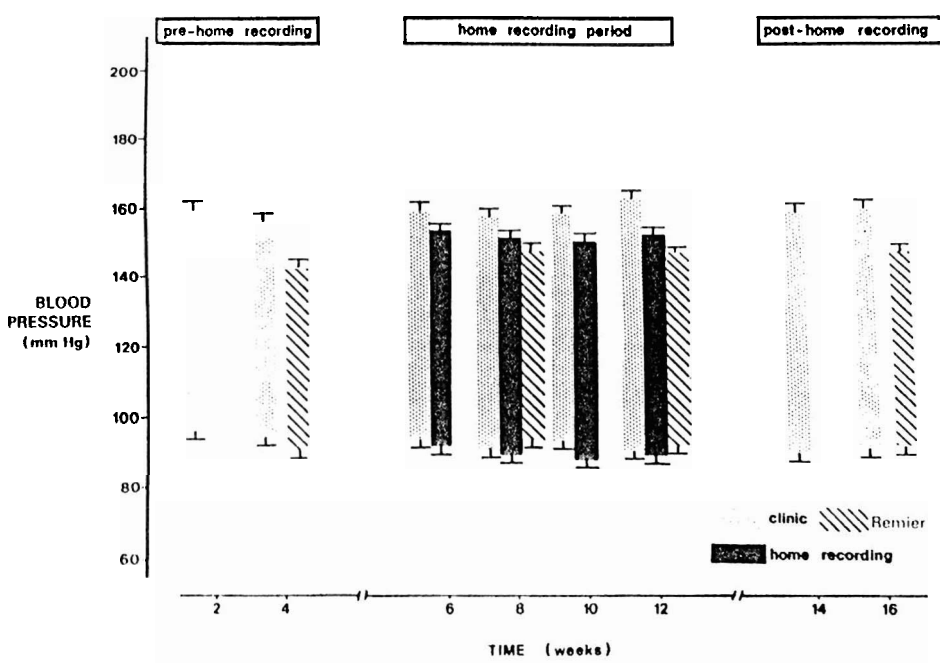

Figure 1. Clinic, home and ambulatory blood pressures in 18 patients.

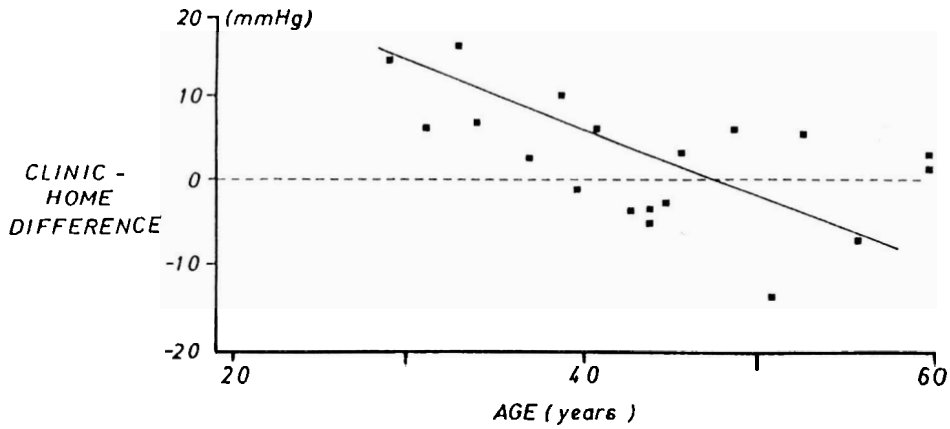

Figure 2. Home–clinic differences related to age.

Table 2. Correlation between home (HBP), clinic (CBP), and ambulatory (ABP) blood pressure measurement, and differences between methods and age for systolic and diastolic pressures in 18 patients

	Systolic		*Diastolic*	
	r	*p*	*r*	*p*
CBP v. ABP*	0.44	<0.05	0.836	<0.001
CBP v. HBP*	0.67	<0.01	0.821	<0.001
HBP v. ABP	0.509	<0.05	0.824	<0.001
Age v. CBP–HBP difference	−0.263	n.s.	−0.509	<0.05
Age v. CBP–ABP difference	0.265	n.s.	0.017	n.s.

* *Comparison of means during the home-recording period.*

Discussion

This study confirms that patients can be trained to record blood pressure accurately, and that only a short period of training is required [3, 4]. As reported in other studies home-recorded systolic blood pressure was lower than that recorded in the clinic [4, 5]. The difference between clinic and home blood pressure recordings varies widely between studies, possibly reflecting differences in the patients studied as clinic–home differences increase with the level of blood pressure and decreases with age and duration of clinic attendance [15].

Home-recorded blood pressures were higher than ambulatory blood pressure and were nearer to clinic pressures, as has been observed by Gould *et al.* [3]. Differences between clinic and ambulatory blood pressure measurements are of clinical importance since ambulatory blood pressure recordings may be more accurate in predicting end-organ disease in hypertensive subjects [1].

In this study blood pressure control, as determined in the clinic and by ambulatory monitoring during normal daily activities, was unaltered during the phase of home recording. Although previous reports have suggested that home

recording of blood pressure by hypertensive patients, both treated and untreated, lowers blood pressure these studies were poorly controlled [7–9] or antihypertensive treatment was altered as required [7, 9] and may have been influenced by the level of blood pressure measured at home. Furthermore, the fall in blood pressure was most marked in the initial period of home recording [8] and may have reflected the tendency for blood pressure to decrease with repeated measurement [16]. In addition the conclusion of previous studies that home recording by patients may influence blood pressure control was based on clinic measurements. In this study patients were untreated and the lack of any effect on clinic blood pressure control was confirmed by ambulatory recordings.

Acknowledgements

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Application of cusums to ambulatory blood pressure data: a simple statistical technique for detecting trends over time

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Keywords: Twenty-four-hour ambulatory blood pressure, cusums.

Review

Ambulatory blood pressure measurement monitoring has become an increasingly important method of investigation in hypertension [1] and automated non-invasive devices which allow frequent measurements of ambulatory blood pressure and the pulse rate over 24 h are now available. The accuracy [2] and the reproducibility [3] of ambulatory measurements have been documented. However, data from ambulatory blood pressure monitoring are characterized by wide scatter, due to random variability, short-term fluctuations with posture, physical and mental activity and long-term variability with seasonal [4], dietary [5,6] and hormonal [7] changes. Superimposed upon the distribution of data there is also the influence of diurnal blood pressure variation.

It is difficult to detect early trends when data collected at regular time intervals show wide scatter. The calculation of cumulative sums ('cusums') is a simple statistical technique which allows early and precise detection of trends in data of this nature. Although described in the medical literature over a decade ago [8,9], this technique is still uncommon in clinical medicine. It is particularly appropriate for the analysis of data derived from 24 h ambulatory blood pressure monitoring.

The cusums technique consists of the selection of an arbitrary reference value, such as the mean of daytime blood pressure, which is then subtracted from each point in succession. The successive deviations of each data point from the reference value are then added cumulatively, i.e. the first to the second, the sum of these to the third and so on. The 'cumulative sums' derived in this manner are then plotted against time with the ambulatory blood pressure data. The reference value chosen is typically the mean of an initial series of observations. However, the overall mean or any other clinically relevant reference point may be used.

Figures 1 and 2 illustrate cusum plots of blood pressure superimposed on the original ambulatory blood pressure data recorded over 24 h in a normotensive subject. The reference value used in Fig. 1 (122/80 mmHg) is the mean of all recordings. Minor changes in the mean of the original data from the baseline are detected by a change in the slope of the cusum plot. The point-in-time of change is accurately identified and the statistical significance of changes in trend is readily calculated [10,11]. Any reference value, arbitrarily chosen from the same data set, will yield a cusum plot giving the same point of change. Figure 2 shows the data from the same subject using a different reference value, the mean daytime (0800–2400 h) blood pressure (128/83 mmHg). While the slope of the cusum plot is necessarily different, the point of change in slope is the same as in Figure 1 and is as readily identified. However, the selection of the mean daytime ambulatory blood pressure as a reference value illustrates the point of change more clearly by bringing the plots of daytime blood pressure and cusum closer together.

The cusum technique has a number of uses in ambulatory blood pressure measurement: diurnal patterns may be identified; the time and the extent of the nocturnal blood pressure fall are readily appreciated from the illustrated plots; the nature of blood pressure variability and its relationship with situational and biological factors such as sleep, level of activity, stress, the heart rate and hormonal activity may be carefully analysed; subgroups of hypertensive patients who display less marked diurnal blood pressure change may be characterized, and the onset and duration of effect of antihypertensive agents may also be identified.

We suggest that cusum plots extend the potential of 24 h ambulatory blood pressure monitoring both in hypertension research and in the clinical assessment of patients with this disorder.

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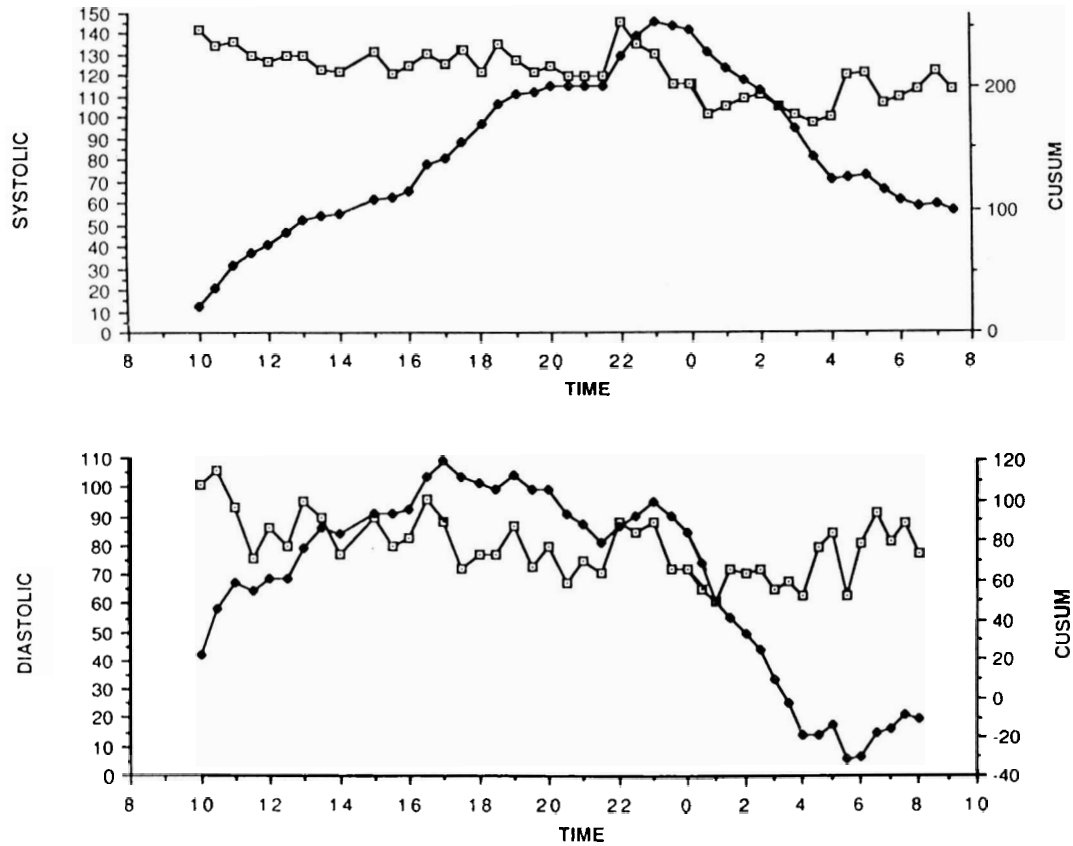

Fig. 1. Ambulatory blood pressure data and derived cusum plots in a normotensive subject. Cusum reference values, 122/80 mmHg. ⊡, systolic; ◆, cusum.

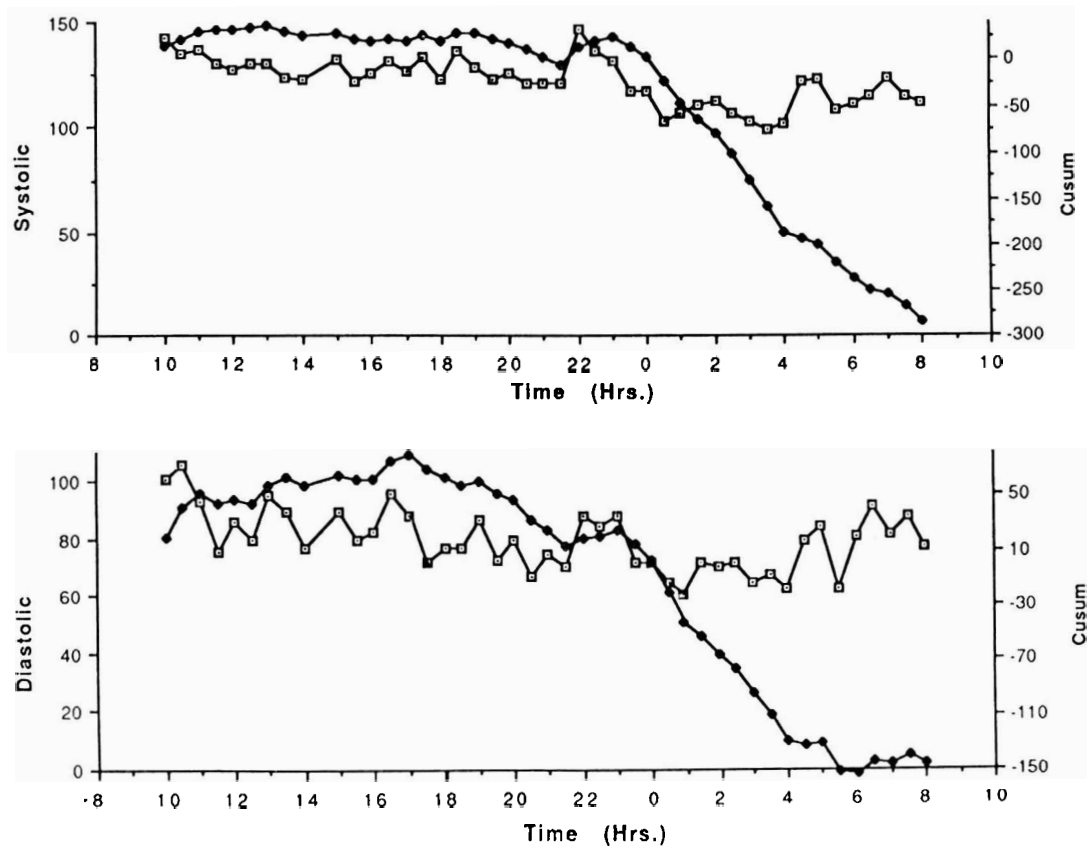

Fig. 2. Ambulatory blood pressure data and derived cusum plot for a normotensive subject (Fig. 1). Cusum reference values, 128/83 mmHg. ⊡ systolic; ◆, cusum.

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