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

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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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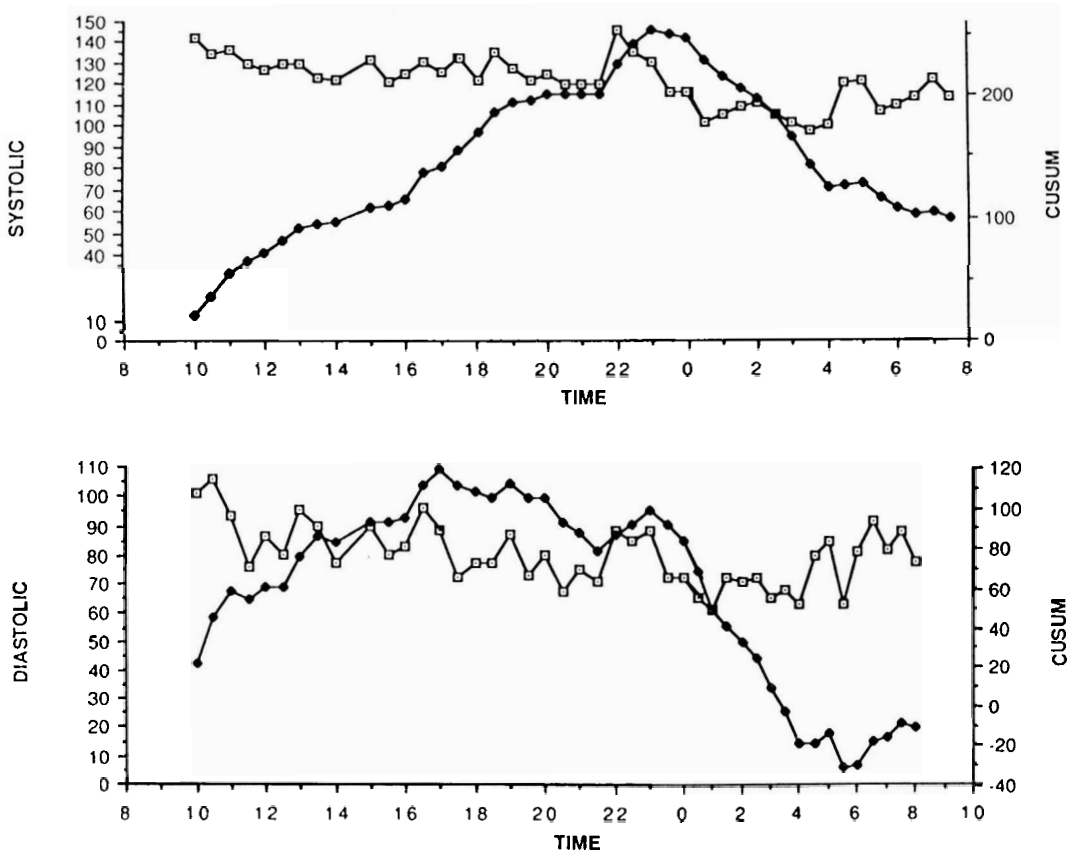

Fig. 1. Ambulatory blood pressure data and derived cusum plots in a normotensive subject. Cusum reference values, 122/80 mmHg. ⊡, systolic; ◆, cusum.

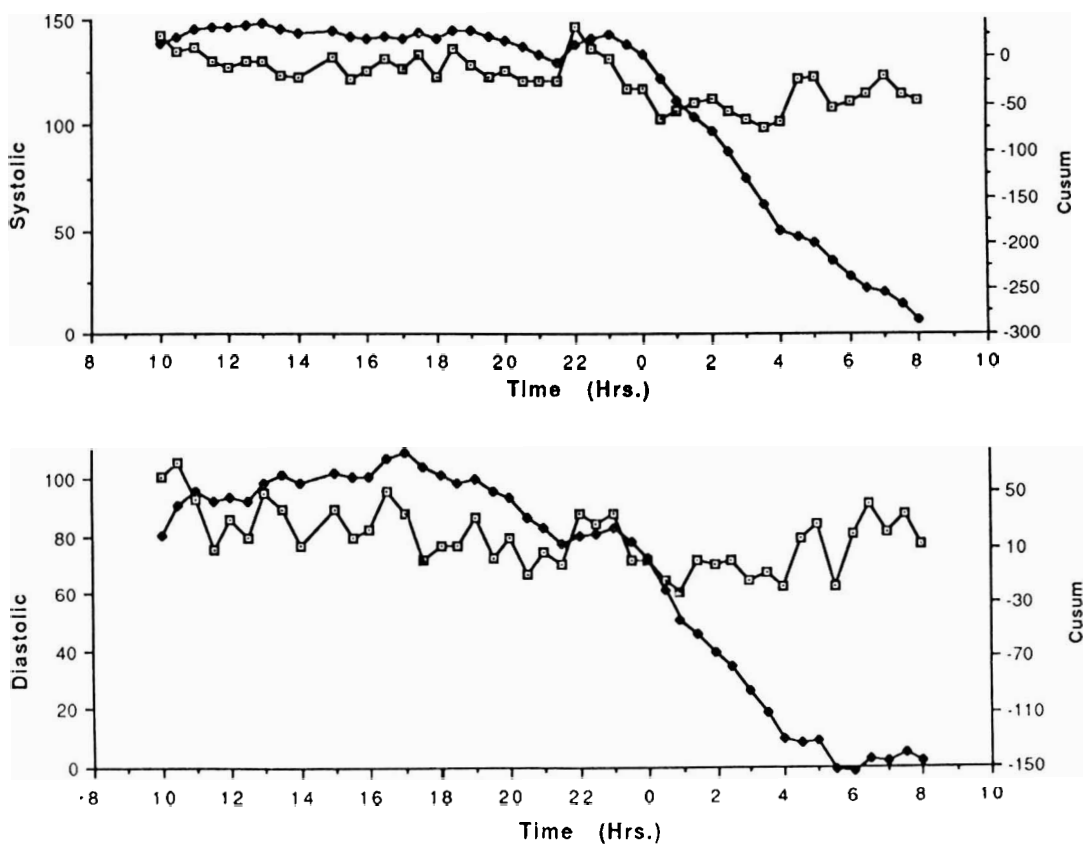

Fig. 2. Ambulatory blood pressure data and derived cusum plot for a normotensive subject (Fig. 1). Cusum reference values, 128/83 mmHg. ⊡ systolic; ◆, cusum.

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