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Ambulatory Blood Pressure Monitoring: An Historical Perspective

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Summary: Since blood pressure was first measured more than 250 years ago, it has been assumed to be a fluctuating phenomenon, but always it has been determined by static measurements in the physician's office. In the 1940s, self-measurement at home was attempted, and two decades later the first ambulatory blood pressure recording devices were developed. These have since been improved, made more convenient, rendered automatic, and are now available for 24-h measurement during a patient's normal day. It is now increasingly recognized that such measurement is more physiologically valid and more accurate in diagnosing hypertension than clinic measurement. In addition, such monitoring may have special utility in assessing response to treatment.

Key words: ambulatory monitoring, clinic blood pressure measurement, blood pressure profile

Introduction

Ever since arterial blood pressure was first measured by Stephen Hales[1] more than 250 years ago, it has been understood that such pressure is not static, but a constantly varying entity. At the same time, physicians have always been advised that the gold standard for blood pressure determination is a small number of clinical measurements made at relatively infrequent intervals.

From these we determine a patient's blood pressure, and on this finding we base our diagnosis and treatment of hypertension.

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Over the years there has been some doubt regarding the reliability of these clinic measurements. Questions about their validity have increased since the development of non-invasive ambulatory blood pressure measurement (ABPM) techniques.

Origin and History of ABPM

One of the first studies questioning the validity of clinic measurement of blood pressure was published in 1940 by Ayman and Goldshine.[2] They instructed 34 of their hypertensive patients to take their own blood pressures or to have family members take them at home. The patients were followed for an average of 22 months, during which time they averaged 21 visits each to the authors' clinic. At the end of the study more than 2,800 clinic blood pressure measurements and more than 40,000 home measurements had been made and recorded.

The authors reported that in every one of the 34 cases the blood pressure readings taken at home were lower than those taken in the clinic by the doctor. The average home readings were roughly 50 mmHg systolic and 25 mmHg diastolic less than the average clinic readings.

We now know that there are a number of limitations to office measurements, and that these limitations result in errors in the estimate of true blood pressure. There is the well-recognized possibility of bias and error on the part of the physician or other individual taking the blood pressure. There is the documented variability of blood pressure, suggesting that a few measurements made at infrequent intervals may result inevitably in an imprecise estimate of the average level of blood pressure.[3] Finally, there is the error arising from what is sometimes called the "white coat" effect, that is, the tendency of blood pressure to go up in the presence of a physician.[4]

All of these limitations can be circumvented by ambulatory monitoring. ABPM takes measurements automatically rather than by a fallible observer, increases by many times the number of readings, and takes these observations outside the artificial and possibly intimidating setting of the physician's office.

The development of ABPM originates with the work of Maurice Sokolow, an internist in San Francisco, who was impressed by the fact that many hypertensive patients with very high blood pressures experienced a normal life expectancy. In 1962 he and his colleagues Hinman *et al.* developed the initial semiautomatic ABPM device.[5] It consisted of a blood pressure cuff that was manually inflated by the subject, and a tape recorder on which the Korotkoff sounds were recorded.

Sokolow *et al.* subsequently published a series of classic papers establishing the clinical value of ABPM. These demonstrated the variability of blood pressure during the day and its relatively poor correlation with casual pressures taken in the office.

Sokolow *et al.* were the first to show that ambulatory pressures correlate more closely than clinical pressures with damage to heart and arteries caused by hypertension.[6]

They also provided the only prospective study showing that ambulatory blood pressure improves the ability to predict risk.[7] In this study, they followed 1,076 patients by ABPM and clinic visits at 1 to 3-month intervals for up to 16 years. They found a significantly greater 10-year incidence of both fatal and nonfatal cardiac events among those with higher than predicted ABPM pressures than in those with lower than predicted ABPM pressures. Office blood pressures were comparable in the two groups.

More recently, intra-arterial ambulatory monitoring requiring catheterization of the brachial or radial artery was introduced in England. This form of ABPM contributed much scientific information, but it has not had much impact clinically and probably never will. During the past few years, vast changes in the technology of noninvasive monitors has occurred, and the current devices are not much bigger than an ordinary handheld tape player.

In addition, they are reliable and quiet, can be programmed to be fully automatic, and can be worn with little discomfort.

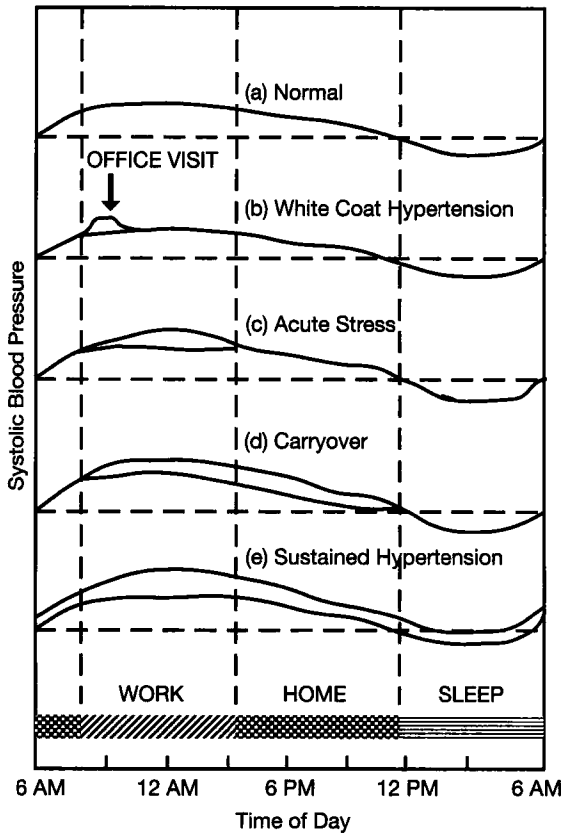

FIG. 1 Theoretic 24-h blood pressure profiles showing different time courses of the effects of "stress" on blood pressure. Panel (a) shows normal diurnal pattern; (b) is white coat hypertension, with elevated pressure only during office visits; (c) shows effects of acute stress, e.g., associated with work; (d) shows "carryover," i.e., effects on blood pressure outlast the duration of stress; and (e) shows the pattern seen in most hypertensive patients, with a sustained elevation of pressure. (Reproduced with permission of *Am Heart J*, Ref. 8.)

Attributes of ABPM

Ambulatory monitoring enables us to record blood pressures during the normal 24-h activities of work, other daytime pursuits, and sleep. Such recordings demonstrate the well-known diurnal pattern of blood pressure, with higher pressures in the afternoon, lower readings in the evening, with the nadir during sleep, and the well-reported early morning surge starting at about 6 a.m. Figure 1 shows in schematic form a series of 24-h blood pressure profiles demonstrating the effects of various influences, such as stress, hypertension, and other factors on the circadian curve. Panel B illustrates the sudden rise in blood pressure during clinic measurement. This is an example of white coat hypertension, defined as an elevated clinic pressure but a normal ABPM pressure.

This phenomenon is said by some to be merely a generalized response to stress, but as Table I indicates, this is not necessarily the case. This is a summary of ABPM recordings of an Israeli fighter pilot found to be hypertensive in the clinic. He was monitored while flying a light plane, at rest, and when flying an F-16 fighter plane, generally regarded as a stressful task. As can be seen, his diastolic blood pressure was 100 mmHg while flying the F-16, and 103 mmHg while having his blood pressure checked

TABLE I White coat hypertension in an Israeli fighter pilot

	BP (mmHg)	HR (beats/min)
Clinic	137/103	62
Flight-Cessna	122/92	69
Rest-briefing	127/92	65
Flight F-16	137/100	92

by his physician, and his systolic blood pressures were the same in both instances, 137 mmHg.

Conclusions

We have three methods of measuring blood pressure: clinic readings, still regarded as the gold standard; self-monitoring at home; and ambulatory monitoring. The latter will play an increasing role in both the diagnosis of hypertensive patients and in the evaluation of their response to treatment.

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