REVIEW

Twenty four hour ambulatory blood pressure monitoring: a new tool for determining cardiovascular prognosis

K Madin, P Iqbal

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Twenty four hour ambulatory blood pressure monitoring (24-H ABPM) plays an important part in the management of subjects with suspected and confirmed disorders of blood pressure regulation. This article reviews the prognostic significance of various aspects of the 24-H ABPM and describes the authors experience in Chesterfield. Over the course of 12 month period from 1 August 2002, 1264 subjects had 24-ABPM. A total of 1187 (93.91%) subjects were included in this study, with mean age of 59.30 years and male:female ratio was 46%:54 %. Fifty two (4.38%) of the subjects had all of the seven features associated with an adverse prognosis. Only 82 (6.90%) subjects had none of the seven adverse prognostic features with the remainder having one or more adverse prognostic features.

Of the various components of 24-H ABPM, night time systolic BP (SBP), night time diastolic blood pressure, daytime SBP were shown to be superior to CBP in predicting five year risk of cardiovascular death. The hazard ratios (after adjustment for age, sex, body mass index, presence of diabetes mellitus, history of cardiovascular events, smoking status, and CBP level) for each 10 mm Hg increase in systolic BP were 1.12 (1.06–1.18; $p < 0.001$) for daytime and 1.21 (1.15–1.27; $p < 0.001$) for night time SBP. The hazard ratios for each 5 mm Hg increase in DBP were 1.02–1.07 ($p = \text{NS}$) for daytime and 1.09 (1.04–1.13; $p < 0.01$) for night time pressures.

The Dublin outcome study was the first large scale study in a western hypertensive population to assess prognostic significance of 24-H ABPM. It confirmed the findings from the earlier Japanese Ohasama study,³ which showed the risk of cardiovascular mortality was significantly related to the highest quintiles of 24-H SBP, 24-H DBP, daytime SBP, daytime DBP and night time DBP, whereas there was no significant association between screening CBP and the cardiovascular mortality. The risk of cardiovascular mortality tended to increase for the highest quintile of night time SBP (≥ 132 mm Hg) although the difference was not statistically significant.

The Dublin outcome study² and the Ohasama study³ did not take into account change in base line blood pressure as a result of treatment. In patients with treated hypertension, a higher ambulatory day and night time SBP and DBP have been shown to predict cardiovascular events even after adjustment for classic risk factors including office blood pressure values⁴

The superiority of 24-ABPM over CBP in predicting mortality is probably related to many factors such as its ability to measure BP during sleep, ability to diagnose subjects with white coat hypertension, and masked hypertension. In addition CPB measurement are not always accurate because of poorly calibrated and maintained CBP instruments, interobserver/intraobserver variability, terminal digit preference even among well trained observers^{5,6}

Ambulatory pulse pressure (A-PP)

The pulse pressure (PP) is defined as the difference between peak SBP and the end DBP. Office/clinic pulse pressure has been shown to be

Abbreviations: 24-H ABPM, 24 hour ambulatory blood pressure monitoring; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure

Twenty four hour ambulatory blood pressure monitoring (24-H ABPM) plays an important part in the management of subjects with the suspected and confirmed disorders of blood pressure regulation. The list of indications for 24-H ABPM is growing (box 1) and the latest addition to this list is the use of 24-H ABPM as a tool for defining cardiovascular prognosis

By taking repeated measurement of blood pressure at predetermined intervals ranging from 10 to 60 minutes during the day and night, 24-H ABPM provides a wealth of information about overall blood pressure profile. Most of the information obtained on 24-H ABPM has been shown to be of prognostic significance and in this article we will discuss seven features shown to be associated with an adverse cardiovascular prognosis (box 2).

AMBULATORY DAYTIME AND NIGHT TIME SYSTOLIC AND DIASTOLIC BLOOD PRESSURE

Clinic BP (CBP) has been shown to be directly related to vascular mortality, with each 20 mm Hg rise in SBP from 115 mm Hg and each 10 mm Hg rise in diastolic BP (DBP) from 75 mm Hg being associated with at least twofold difference in the death rate from stroke as well as coronary heart disease.¹

Comparing CBP with the 24-H ABPM over a median follow up period of 8.4 years, the Dublin outcome study² was able to show that ambulatory measurement of blood pressure is superior to clinic measurement in predicting five year risk of cardiovascular death (fig 1).

See end of article for authors' affiliations

Correspondence to:
Dr P Iqbal, Chesterfield
Hypertension Clinic,
Chesterfield and North
Derbyshire Royal Hospital
NHS Foundation Trust
Hospital, Calow,
Chesterfield S44 5BL, UK;
Pervaiz.Iqbal@chesterfield-
royal.nhs.uk

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Figure 1 Superiority of ambulatory over clinic blood pressure measurement in predicting mortality: the Dublin outcome study.² (Reproduced by kind permission of the publishers Lippincott Williams and Wilkins, Baltimore, USA).

an independent risk factor for fatal and non-fatal coronary heart disease in the Framingham study.⁷ It has also been shown that high PP in patients with hypertension may be a marker of pre-clinical cardiovascular disease.⁸

The PIUMA study⁹ was the first to show that average 24-H A-PP was a strong independent predictor of cardiovascular morbidity and mortality in apparently healthy subjects with essential hypertension. Cardiovascular morbidity was significantly better predicted by A-PP than by office PP even after controlling for multiple risk factors (age, sex, LV hypertrophy, cholesterol, diabetes, smoking, white coat hypertension, and non-dipper status).

Average 24-H A-PP has also been shown to be a powerful predictor of cardiovascular morbidity in elderly men, independent of office PP¹⁰ and 24-H mean or SBP.¹¹ In younger subjects neither office nor ambulatory PP have been shown to be associated with an increased cardiovascular risk.^{4, 12}

High PP may result from increased SBP secondary to arterial stiffness, decreased DBP, or both. High SBP increases vascular load and low DBP can decrease coronary perfusion, both of which provide pathophysiological explanations for the prognostic value of PP.

Dipping status (dippers and non-dippers)

24-H ABPM provides a unique opportunity to measure blood pressure at pre-determined intervals during sleep and to assess dipping status. Non-dippers are defined as those who

show a reduction in BP of less than 10% between the average day and night BP. In contrast “extreme dippers” are those in whom average BP values are less than 20% lower at night.

Non-dipping status has been shown to be associated with a higher prevalence of target organ damage and vascular events such as left ventricular hypertrophy,¹³ intima-media thickness, and atherosclerotic plaques in women,¹⁴ higher urinary protein excretion,¹⁵ and increased cardiovascular morbidity and mortality.^{16, 17}

Loss of nocturnal dip has also been described in patients with chronic renal failure^{18, 19} and diabetes mellitus²⁰ two conditions associated with very high CV morbidity and mortality.

Higher CV risk associated with non-dipping is thought to be related to raised sympathetic tone, raised renal sodium re-absorption resulting in higher night time BP to drive pressure natriuresis, with the latter responding to low sodium diet and renal transplantation.^{21, 22}

Morning surge and morning hypertension

In most people, SBP and DBP are at their highest during the day. As the evening progresses, there is a steady fall in BP, reaching the lowest level between midnight and 2 am. From 2 am there is a slow but steady rise in SBP and DBP, which becomes much steeper from 4 am until BP values reach to daytime levels. In most people the rise in SBP and DBP in the morning is less than 20/15 mm Hg and BP values rarely exceed 140/90 mm Hg. 24-H ABPM provides a unique opportunity to study morning surge and morning hypertension in detail.

Defining morning surge as the increase from the lowest BP during sleep to the average of the first two hours after waking, Kario *et al*²³ were able to show that elderly subjects with morning surge had a higher baseline prevalence of multiple cerebral infarcts (57% compared with 33%,

Box 1 Indications for 24 hour ambulatory blood pressure monitoring

- Borderline hypertension
- Variable clinic blood pressure
- Suspected white coat hypertension
- Suspected white coat effect
- Resistant hypertension
- Hypertension in pregnancy
- Hypertension in elderly patients
- Evaluation of symptoms suggesting postural hypotension
- Evaluation of symptoms suggesting drug induced hypotension
- Blood pressure evaluation in patients with the suspected or confirmed autonomic dysfunction
- As an overall guide to hypertension treatment
- As a prognostic cardiovascular tool

Box 2 Prognostic features of 24 hour ambulatory blood pressure monitoring

- Daytime ambulatory systolic blood pressure
- Daytime ambulatory diastolic blood pressure
- Night time ambulatory systolic blood pressure
- Night time ambulatory diastolic blood pressure
- Ambulatory pulse pressure
- Presence or absence of nocturnal dip
- Presence or absence of morning surge/morning hypertension

Table 1 Demographic and blood pressure characteristics

Characteristics	Mean (SD)	Normal
Age (years)	59.30 (13.94)	
Sex		
Male	547 (46%)	
Female	640 (54%)	
Clinic SBP	164.51 (23.47)	
Clinic DBP	92.11 (22.44)	
Total 24 hour pulse pressure	55.23 (11.74)	<50 mm Hg
50–59.9 mm Hg	393 (53.40%)	
60–69.9 mm Hg	214 (29.08%)	
70+ mm Hg	129 (17.53%)	
Daytime ambulatory SBP (mm Hg)	138.66 (15.46)	<135 mm Hg
Daytime ambulatory DBP (mm Hg)	82.65 (11.47)	<85 mm Hg
Night time ambulatory SBP (mm Hg)	126.22 (16.16)	<120 mm Hg
Night time ambulatory DBP (mm Hg)	71.13 (10.97)	<75 mm Hg
Nocturnal dip (SBP)*	502 (42.29%)	>10%
Early morning SBP (mm Hg)†	154.71 (13.16)	≤140 mm Hg
Early morning DBP (mm Hg)†	97.88 (6.93)	≤90 mm Hg
Early morning hypertension‡		
Isolated systolic hypertension	396 (33.36%)	≥140 mm Hg
Isolated diastolic hypertension	283 (23.84%)	≥90 mm Hg
Morning surge (mm Hg)§		
SBP	22.86 (16.31)	≥20 mm Hg
DBP	22.03 (11.89)	≥15 mm Hg

SBP, systolic BP; DBP, diastolic BP; daytime, 7 am–11 pm; night time, 11 pm–7 am. The daytime and night time blood pressure is the average of readings taken during the day time and night time respectively. *Nocturnal dip, decrease in average night time SBP of 10% or more, when compared with the average day time SBP. †Early morning SBP/DBP, the average of first two SBP/DBP readings taken in the morning from 7 am at 30 minute intervals. ‡Early morning hypertension, early morning BP of ≥140/90 mm Hg. §Morning surge, difference between lowest SBP and DBP recorded at night and the average of the first two readings taken in the first hour (7–8 am) in the morning. Altogether 559 (47.09%) had morning surge ≥20/15 mm Hg.

$p = 0.001$) and a higher incidence of stroke (19% compared with 7.3% $p = 0.004$) compared with those whose BP did not show morning surge. In addition, it was shown that in the group with morning surge the stroke events were independent of 24-H ABPM, Nocturnal dipping status and base line prevalence of silent infarcts ($p = 0.008$). Morning surge has also been shown to be associated with left ventricular hypertrophy in people with untreated hypertensive.²⁴

Defining morning hypertension as ambulatory BP ≥135/85 mm Hg in the first hour after waking, Redon *et al*²⁵ showed that in treated patients prevalence of morning hypertension ranged from 52% in those with normal clinical BP (<140/90) to 72% in those with high clinical BP (>140/90).

Morning surge and morning hypertension are thought to be implicated in excess cardiovascular mortality and morbidity in the early hours of the morning.^{26–27}

CHESTERFIELD EXPERIENCE

Over the course of 12 months from the 1 August 2002, 1187 people had 24-H ABPM performed at the cardiorespiratory laboratory at Chesterfield Royal Hospital (table 1). These patients were referred either from local general practices on an open access basis, from hypertension clinics, or from general medical clinics within the hospital. In every case these patients had at least one of the recognised requirements

for 24-H ABPM (box 1). Patients were asked to carry on with their normal daily activities as usual during the course of monitoring. Each subject had BP taken at half hourly intervals during the day (7 am to 11 pm) and hourly at night (11 pm to 7 am) to give a total of 40 readings over the course of 24 hours. Some 86.10% of the patients had ≥90% BP measurements successfully recorded.

Each subject had 24-H ABPM analysed and reported by an experienced physician (PI) with careful attention to the presence or absence of the seven adverse monitoring features (box 3).

In situations where subjects had one or more adverse ambulatory features present, appropriate advice was given (change of antihypertensives agents, change of dose, change in the timing of drugs) or treatment to improve blood pressure control and reduce overall cardiovascular risk intensified.

A large proportion of subjects (93%) had one or more adverse features reported on 24-H ABPM (table 2). To the best of our knowledge this has not been reported before

In our district 24-H ABPM has become an integral part of process for diagnostic and prognostic evaluation of patients with hypertension, with a fourfold increase in the request for 24-HABPM over the past seven years. General practitioners

Table 2 Adverse features recorded

	No	%
None	82	6.90
One	163	13.7
Two	175	14.7
Three	174	14.7
Four	198	16.7
Five	179	15.1
Six	164	13.80
Seven	52	4.4

Box 3 Adverse features noted on ABPM

- High daytime ambulatory SBP ≥135 mm Hg
- High daytime ambulatory DBP ≥85 mm Hg
- High night time ambulatory SBP ≥120 mm Hg
- High night time ambulatory DBP ≥75 mm Hg
- Absent nocturnal dip ≤10% decrease in systolic BP at night
- Morning hypertension ≥140/90 mm Hg
- High pulse pressure ≥50 mm Hg

are becoming increasingly comfortable with interpretation of 24-H ABPM and are keen to make necessary therapeutic changes to counter many of the adverse features. Using these changes for patients attending our hypertension clinic, most of them with resistant or difficult to control hypertension, we have been able to show that it is possible to achieve control in a significant proportion of these patients.²⁸

CONCLUSION

24-HABPM can provide a wide variety of information of diagnostic and prognostic value. The prevalence of adverse prognostic features was high in our Chesterfield cohort. Such information can alert the physician to modify treatment accordingly, either by changing the type, dose, or timing of antihypertensives agents, or by intensifying treatment for high BP and coexisting cardiovascular risk factors. We have shown previously that general practitioner do pay attention to the pharmacological treatment advice given.²⁹

Authors' affiliations

K Madin, P Iqbal, Chesterfield Hypertension Clinic, Chesterfield and North Derbyshire Royal Hospital NHS Foundation Trust Hospital, Chesterfield, UK

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