Position statement

Ambulatory blood pressure monitoring

November 2010

National Heart Foundation of Australia and the High Blood Pressure Research Council of Australia
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About this position statement

This document updates the Heart Foundation’s 2002 position statement, Ambulatory blood pressure monitoring.\(^1\) It incorporates revised blood pressure (BP) thresholds for the diagnosis and management of hypertension.\(^2,3\)

This position statement was developed by the Ambulatory Blood Pressure Monitoring Working Group (a subcommittee of the National Heart Foundation of Australia’s National Blood Pressure and Vascular Disease Advisory Committee) and has been ratified by the Heart Foundation’s Cardiovascular Health Advisory Committee and the High Blood Pressure Research Council of Australia. The working group considered the best available evidence from clinical trials and controlled observational studies, together with clinical expertise (Appendix A).

Context

This position statement supplements current national guidelines for the diagnosis and management of hypertension in adults.\(^2\)

Current Australian, international and most national guidelines for the management of hypertension emphasise that the necessity, choice and intensity of BP-lowering treatment should be determined by the individual’s probability of an event within a given period (absolute CVD risk),\(^4\) based on thorough assessment and consideration of all risk factors (e.g. age, sex, waist circumference and/or body mass index, lifestyle, family history, blood lipids, glucose metabolism) and the presence of associated clinical conditions and/or end-organ damage.\(^2\)
## Summary of key points

**ABP monitoring:**
- provides BP readings for daytime (awake), night-time (asleep) and 24-hour average, and provides data to calculate other parameters including BP variability and load.
- provides more reliable assessment of actual BP than clinic BP
- enables detection of white-coat and masked hypertension
- identifies nocturnal ‘non-dippers’, who have a worse prognosis
- enables better prediction of end-organ damage associated with elevated BP, and risk of future cardiovascular events, than clinic or occasional BP measurements
- provides a reliable guide to therapy
- is cost-effective.

ABP monitoring should be arranged, where possible, when any of the following apply:
- suspected white-coat effect (including suspected white-coat hypertension). Patients with white-coat hypertension confirmed by ABP monitoring are at increased risk of hypertension and end-organ damage, and require continuing BP monitoring.
- suspected masked hypertension
- borderline hypertension
- before commencing an antihypertensive medicine regime
- hypertension despite appropriate treatment (including isolated systolic hypertension in the elderly)
- high risk of future cardiovascular events
- known or suspected episodic hypertension
- suspected sleep apnoea
- syncope or other symptoms suggesting orthostatic hypotension, where this cannot be demonstrated in the clinic
- possibility of autonomic failure
- hypertension of pregnancy.

Data obtained from ABP monitoring must be interpreted carefully with reference to diary information and timing of medicines.

Reference ‘normal’ ABP values for non-pregnant adults are:
- 24-hour average < 115/75 mmHg
- Daytime (awake) < 120/80 mmHg
- Night-time (asleep) < 105/65 mmHg.

ABP thresholds for hypertension in adults are:
- Average over 24 hours ≥ 130/80 mmHg
- Daytime (awake) ≥ 135/85 mmHg
- Night-time (asleep) ≥ 120/75 mmHg.

ABP values above ‘normal’ and below thresholds for hypertension are considered ‘high-normal’.

Night-time (sleeping) average systolic and diastolic BP should both be at least 10% lower than daytime (awake) average.

BP load (percentage time during which BP readings exceed hypertension threshold over 24 hours) should be < 20%.

BP variability, maximum systolic BP and morning BP surge should also be taken into account (and targeted by treatment).

Treatment targets based on ABP are lower than for clinic BP readings.

Ideally, ABP monitoring should be performed by specialist monitoring centres.

Only appropriately validated devices should be used for ABP monitoring.

Arm circumference should be measured to select the correct cuff size.

ABP readings may not be accurate when taken during exercise, movement or driving, or when the cardiac rate is irregular.
Measuring ABP

Ambulatory blood pressure (ABP) monitoring involves the patient wearing a portable BP measuring device for a specified period (usually 24 hours), during which periodic BP measurements (usually every 20–30 minutes) are automatically taken via a cuff worn on the upper arm. The resulting series of BP readings, taken throughout the person's normal daytime activities and during sleep, provides a robust assessment of the impact of BP on the person's cardiovascular system (BP load).

ABP monitoring systems provide measures of BP and heart rate during the daytime, night-time, and while awake and asleep. The data can be used to calculate a range of parameters associated with CVD risk, including BP variability, heart rate (HR) variability, BP load and morning BP (see Interpreting ABP).

Rationale for ABP monitoring in clinical practice

<table>
<thead>
<tr>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABP monitoring:</strong></td>
</tr>
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<td>• provides BP readings for daytime (awake), night-time (asleep) and 24-hour average, and provides data to calculate other parameters including BP variability and load.</td>
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<tr>
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</tr>
<tr>
<td>• is cost-effective.</td>
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</table>

**ABP reflects actual BP more closely than clinic measurements**

BP measurements taken in the clinic or at home provide limited information about the individual's actual BP profile (Table 1). Clinic BP readings can be affected by:

• measurement errors due to defective instruments, improper techniques or observer bias

• circumstances that exert a pressor effect. This is referred to as the white-coat effect and can result in white-coat hypertension (isolated clinic hypertension) (see White-coat effect and suspected white-coat hypertension)

• circumstances that mask elevated BP. The converse of white-coat hypertension is referred to as masked or 'reverse-white-coat' hypertension (see Suspected masked hypertension). Occasional (casual) clinic BP measurements only indicate daytime BP status and do not provide information about the circadian BP pattern, which is influenced by a
variety of factors (e.g. ambient temperature and humidity, physical activity, consumption of alcohol, caffeine and food, emotional states such as anxiety and anger, and sleep-wake routine).

Table 1. Comparison of clinic, home and ambulatory measures of BP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Clinic</th>
<th>Home †</th>
<th>Ambulatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnosis of hypertension</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Evaluation of antihypertensive therapy</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Prediction of cardiovascular events</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>White-coat hypertension</td>
<td>No</td>
<td>Yes (limited)</td>
<td>Yes</td>
</tr>
<tr>
<td>Masked hypertension</td>
<td>No</td>
<td>Yes (limited)</td>
<td>Yes</td>
</tr>
<tr>
<td>Presence/absence of nocturnal dipping</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Morning hypertension</td>
<td>No</td>
<td>Yes (limited)</td>
<td>Yes</td>
</tr>
<tr>
<td>Short-term day and night BP/HR variability</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Long-term BP variability (if repeated)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BP load</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Standardised international protocols for validation exist</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Parameters measured or clinical conditions that can be detected by properly interpreted ABP monitoring; † Self-measured BP

Table adapted from reference 5

ABP is a better predictor of clinical outcomes and end-organ damage

Prospective studies have shown that ABP is a stronger predictor of clinical outcomes than conventional clinic BP measurements. 6–10

End-organ damage associated with elevated BP, such as left ventricular hypertrophy (LVH), is more strongly correlated with ABP than with clinic BP measurements. 11–14

ABP also correlates more closely with renal and vascular surrogate markers of end-organ damage such as microalbuminuria and carotid artery wall thickness. 15

ABP monitoring can detect absence of nocturnal BP dipping

Most studies investigating the significance of night-time hypertension have reported that night-time (sleeping) BP is more important in predicting clinical outcomes than daytime (awake) BP, 7, 9, 16, 17 particularly in people with hypertension who do not show normal BP reduction ('dipping') during sleep. Nocturnal non-dipping is associated with increased risk of stroke, end-organ damage and cardiovascular events including death. 7, 16, 18, 19

ABP monitoring is the only commonly used practical method to determine the presence or absence of nocturnal BP dipping (see Interpreting ABP).
**ABP monitoring is cost-effective**

ABP monitoring costs more to perform than conventional clinical measurements.\(^1\) However, there is consistent evidence that the additional cost is offset by more reliable diagnosis of hypertension\(^2\) and that the use of ABP may avoid unnecessary drug therapy in the follow-up period.\(^3\)\(^,\)\(^4\)

Rational prescribing of antihypertensive treatment based on accurate BP assessment may lead to cost savings.\(^3\) For example, pharmacological therapy can often be deferred in patients with white-coat hypertension confirmed by ABP monitoring (although they require monitoring and lifestyle management of BP). In patients with hypertension who also show an additional white-coat effect during clinic BP measurements, confirmation of actual BP profile by ABP monitoring may enable medication doses to be reduced (see *White-coat effect and suspected white-coat hypertension*).

The cost of providing good control of hypertension in an individual can be up to four times higher using conventional clinic BP measurements.\(^5\) The cost–benefit ratio is expected to improve as the cost of managing hypertension rises with increasing rates of diagnosis and prescribing of new, more expensive antihypertensive agents.

**When is ABP monitoring useful?**

<table>
<thead>
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<td>• hypertension despite appropriate treatment (including isolated systolic hypertension in the elderly)</td>
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<tr>
<td>• possibility of autonomic failure</td>
</tr>
<tr>
<td>• hypertension of pregnancy.</td>
</tr>
</tbody>
</table>

\(^1\) The costs to the patient are reimbursable by the Department of Veterans Affairs (eligible patients only) but are not currently reimbursed by Medicare.
While ABP monitoring is generally recommended for reliable assessment of 24-hour BP pattern, it is particularly valuable in the following clinical situations.

**White-coat effect and suspected white-coat hypertension**

In some patients, the BP measurement process itself can induce a higher-than-normal BP (known as the white-coat effect). This effect is particularly noticeable when BP is measured by a doctor, and much less pronounced when BP is measured by a nurse or another trained staff member within the clinic. Recent studies suggest that the magnitude of white-coat effect can be reduced by taking clinic BP measurements using an automated device while the person is alone in a quiet examining room.

White-coat hypertension (isolated clinic hypertension) refers to the condition in which a person meets criteria for hypertension when measured in the clinic but shows normal BP levels when measured at home or by ABP monitoring. It occurs in approximately 10–20% of the general population. Factors that make white-coat hypertension more likely in a person with raised clinic BP include:

- female sex
- non-smoker
- few recorded clinic BP measurements
- borderline hypertension
- recent-onset hypertension
- absence of evidence of end-organ damage.

When white-coat hypertension is suspected in a person otherwise at low risk of CVD, ABP monitoring should be performed to provide a more comprehensive and reliable assessment of the person’s BP levels during daily activities (Figure 1). It is preferable to home BP measurement because it can avoid a self-induced pressor effect.

White-coat hypertension has been associated with:

- higher anxiety scores
- increased (approximately double) risk of hypertension within 8–10 years, compared with those with normal BP
- increased risk of developing impaired fasting glucose, raised glucose or diabetes.

Accordingly, white-coat hypertension confirmed on ABP monitoring warrants careful assessment, including thorough investigation for end-organ damage and management of CVD risk factors (including glucose intolerance and lifestyle risk factors). The diagnosis should be confirmed by repeated ABP monitoring or self-monitoring using home BP, and repeated every 1–2 years.

White-coat hypertension does not appear to respond to standard antihypertensive drug therapy consistently, but large randomised controlled trials are needed to investigate this issue.
Figure 1. Investigation and management of suspected white-coat hypertension in patients at low risk of CVD

Flow diagram for management of BP in patients with suspected white-coat hypertension, who are otherwise thought to be at low risk of CVD.

*includes management of lifestyle risk factors, monitoring glucose tolerance (refer to current hypertension management guidelines)

Suspected masked hypertension

Masked hypertension refers to the situation in which clinic measurements are normal but ABP measurements are elevated, which occurs up to 10% of the general population. Possible reasons for failure to detect BP elevation on clinic measurements (particularly in the morning) include evening alcohol consumption and
the use of short-acting antihypertensive agents.\textsuperscript{40} Obstructive sleep apnoea is another important cause of masked hypertension.\textsuperscript{41}

Masked hypertension should be suspected in people with normal clinic BP readings and any of the following.\textsuperscript{32, 41, 42}

- LVH or evidence of other target organ damage
- a history of hypertension in both parents
- multiple risk factors for cardiovascular disease
- obstructive sleep apnoea
- occasional high BP readings.

While the full clinical implications of masked hypertension and its appropriate management are uncertain, this condition has been associated with a worse prognosis than consistent normotension,\textsuperscript{39} including increased risk of developing:

- hypertension within 10 years\textsuperscript{36}
- impaired fasting glucose, raised glucose or diabetes.\textsuperscript{37}

When masked hypertension is suspected, ABP should be performed to provide a more comprehensive and reliable assessment of the person's BP levels during daily activities.

**Borderline hypertension**

ABP monitoring can be useful as a guide to the requirement for antihypertensive drug treatment in patients with high-normal BP on clinic measurements, especially for patients with intermediate CVD risk as assessed by an absolute risk calculator.

**Resistant hypertension**

Resistant hypertension is defined as BP that remains above target despite appropriate doses of antihypertensive agents from at least three different classes including a diuretic, good adherence to treatment and appropriate management of lifestyle risk factors.\textsuperscript{43} Measurement of ABP is indicated in these patients to assess BP pattern and assess the degree to which white-coat effect is contributing to apparent resistance.

**Elderly patients**

ABP monitoring is useful in the investigation of BP in elderly patients because orthostatic hypotension is relatively common, and under- and over-treatment carry particular risks in this group. White-coat hypertension is more common in the elderly, particular for systolic hypertension in women.\textsuperscript{44}

**Autonomic failure, orthostatic (postural) hypotension and syncope**

ABP monitoring can be useful to document orthostatic (postural) hypotension or fluctuating and unstable BP patterns in patients with autonomic failure, which is relatively common in people with diabetes and the elderly. ABP monitoring is especially indicated when symptoms such as posture-related syncope or near-syncope cannot be confirmed in the clinic.
Hypertension in pregnancy

White-coat hypertension is common in pregnant women and is associated with better pregnancy outcomes than true hypertension. However, the usefulness of ABP monitoring in pregnancy is unclear due to a lack of clinical studies comparing ABP monitoring during pregnancy with conventional clinic BP monitoring. Nevertheless, detection of white-coat hypertension by ABP monitoring provides reassurance that antihypertensive agents can be withdrawn (at least initially), provided that BP is monitored throughout pregnancy to detect pre-eclampsia, which occurs in a small subset of women.

Titrating antihypertensive medicines

Antihypertensive therapy based on ABP monitoring, rather than regular clinic measurements, may enable better management with more appropriate adjustment of medication doses required to achieve target BP. ABP may also be a sensitive indicator of loss of BP control.

Patients at high CVD risk

Detection of hypertension and treatment to target is critical in those at high CVD risk identified by existing CVD (e.g. a history of stroke or myocardial infarction), the presence of end-organ damage (e.g. LVH or microalbuminuria) or associated conditions that increase CVD risk (e.g. diabetes or chronic kidney disease). ABP monitoring may be useful in assessing treatment effects and guiding dose titration in these patients.

Episodic hypertension

Episodic hypertension (e.g. in patients with phaeochromocytoma) may not be detected with clinic BP measurements. ABP monitoring for at least 24 hours increases the likelihood of capturing bouts of episodic hypertension that otherwise might be missed.

Suspected sleep apnoea

Because ABP monitoring permits BP measurements during sleep, it can be useful for demonstrating nocturnal dipping or lack of nocturnal dipping in patients with suspected sleep apnoea.
Figure 2. ABP monitoring in patients with high CVD risk
Flow diagram for management of BP in patients at high risk of CVD or in whom masked hypertension is suspected. In these patients it is appropriate to perform ABP monitoring, even if the clinic BP levels are not elevated.

*existing CVD or as assessed using absolute CVD risk calculator, irrespective of BP (refer to current hypertension management guidelines)

† associated conditions: diabetes, cerebrovascular disease, coronary heart disease, chronic heart failure, chronic kidney disease, aortic disease, peripheral arterial disease, hypercholesterolaemia, family history or previous diagnosis of premature CVD or familiar hypercholesterolaemia (refer to current hypertension management guidelines)

‡ end-organ damage: LVH, microalbuminuria, chronic kidney disease, vascular disease (refer to current hypertension management guidelines)
# Interpreting ABP

## Key points

- Data obtained from ABP monitoring must be interpreted carefully with reference to diary information and timing of medicines.

- Reference ‘normal’ ABP values for non-pregnant adults are:
  - 24-hour average < 115/75 mmHg
  - Daytime (awake) < 120/80 mmHg
  - Night-time (asleep) < 105/65 mmHg.

- ABP thresholds for hypertension in adults are:
  - Average over 24 hours ≥ 130/80 mmHg
  - Daytime (awake) ≥ 135/85 mmHg
  - Night-time (asleep) ≥ 120/75 mmHg.

- ABP values above ‘normal’ and below thresholds for hypertension are considered ‘high-normal’.

- Night-time (sleeping) average systolic and diastolic BP should both be at least 10% lower than daytime (awake) average.

- BP load (percentage time during which BP readings exceed hypertension threshold over 24 hours) should be < 20%.

- BP variability, maximum systolic BP and morning BP surge should also be taken into account (and targeted by treatment).

- Treatment targets based on ABP are lower than for clinic BP readings.

ABP readings should be interpreted with reference to patient diary records for sleep, medicines, posture, activity, symptoms and/or other events (see *Instructions for patients*). Actual times for day/night should be used rather than those defined by the software.

Explanatory notes on the selection of thresholds are provided in Appendix B.
‘Normal’ BP levels in adults compared with clinic BP

Current Australian national guidelines for the diagnosis and management of hypertension define ‘normal’ BP for adults as clinic BP < 120/80 mmHg. This category corresponds to the following ABP readings (rounded to nearest 5 mmHg):

- 24-hour average < 115/75 mmHg
- Daytime average < 120/80 mmHg
- Night-time average < 105/65 mmHg.

Classification of hypertension in adults compared with clinic BP

Current Australian national guidelines for the diagnosis and management of hypertension define hypertension in adults as clinic BP ≥ 140/90 mmHg. Equivalent ABP thresholds for hypertension (rounded to nearest 5 mmHg) are:

- 24-hour average ≥ 130/80 mmHg
- Daytime average ≥ 135/85 mmHg
- Night-time average ≥ 120/70 mmHg.

Equivalent ABP thresholds for the classification of hypertension are shown in Table 2. This classification may provide guidance on the appropriate intensity of antihypertensive therapy. For example, daytime ABP > 168/105 mmHg corresponds to clinic BP > 180/110 mmHg, and should therefore trigger immediate initiation of antihypertensive therapy for the management of grade 3 hypertension according to current guidelines, including both pharmacological therapy (commencement of treatment or an increase in dose) and lifestyle risk factor modification regardless of other CVD risk factors.

\(^2\) Current guidelines emphasise that BP-related risk is a continuum with no defined lower cut-point.

\(^{iii}\) Clinic BP measured by trained staff other than doctors

\(^{iv}\) Current guidelines note that the term ‘hypertension’ and classification cut-points are used for practical reasons, on the understanding that individual cardiovascular risk assessment determines appropriate management in each patient.
Table 2. Classification of hypertension in adults

Systolic/diastolic ABP thresholds (not rounded) predicted from clinic BP measured by trained staff (other than doctors) for diagnosis and grading of hypertension (Source: reference 3). These equivalents differ slightly from the rounded recommended values shown in the text.

<table>
<thead>
<tr>
<th>Hypertension</th>
<th>Clinic BP (mmHg)</th>
<th>ABP predicted from clinic BP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24-hour</td>
<td>Night</td>
</tr>
<tr>
<td>Grade 3 (severe)</td>
<td>≥ 180/110</td>
<td>≥ 163/101</td>
</tr>
<tr>
<td>Grade 2 (moderate)</td>
<td>≥ 160/100</td>
<td>≥ 148/93</td>
</tr>
<tr>
<td>Grade 1 (mild)</td>
<td>≥ 140/90</td>
<td>≥ 133/84</td>
</tr>
</tbody>
</table>

Treatment targets in adults compared with clinic BP

Treatment targets based on ABP are lower than those based on clinic BP readings. Like clinic BP treatment targets, ABP targets depend on the individual’s absolute risk of CVD (i.e. targets are lower for patients with or at elevated risk of CVD, including those with associated conditions or end-organ damage).

ABP treatment targets corresponding with current national guidelines are shown in Table 3 (see Appendix A for age- and sex-adjusted targets in patients with moderate-to-high CVD risk). For practical purposes, the clinic target BP can be simply used as the target for the mean daytime BP during ABP monitoring (e.g. for a patient with diabetes, the target for average daytime ABP is less than 130/80 mmHg).  

Table 3. Treatment targets in adults

Systolic/diastolic ABP target values (not rounded) predicted from clinic BP targets (where BP measured by trained staff other than doctors), based on overall cardiovascular risk assessment (Source: reference 3) These equivalents differ slightly from the rounded recommended values shown in the text.

<table>
<thead>
<tr>
<th>Patient group</th>
<th>Clinic BP (mmHg)</th>
<th>ABP equivalents (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24-hour</td>
<td>Night</td>
</tr>
<tr>
<td>Uncomplicated hypertension*</td>
<td>&lt; 140/90</td>
<td>&lt; 133/84</td>
</tr>
<tr>
<td>People with associated clinical conditions or end-organ damage†</td>
<td>&lt; 130/80</td>
<td>&lt; 125/76</td>
</tr>
<tr>
<td>Hypertension plus proteinuria &gt; 1 g/day</td>
<td>&lt; 125/75</td>
<td>&lt; 121/71</td>
</tr>
</tbody>
</table>

*People without any of the following: coronary heart disease, diabetes, chronic kidney disease, proteinuria (> 300 mg/day), stroke or transient ischaemic attack; †People without any of conditions listed at note [*]

Clinic BP measured by trained staff other than doctors
Factors to consider when interpreting ABP

Age and sex effects
Daytime systolic ABP equivalents for those aged over 65 years are 2–4 mmHg lower than those for patients aged 25-44 years, and 1–2 mmHg lower than for patients aged 45–64. Daytime diastolic ABP equivalents do not appear to be affected by age.

Systolic and diastolic ABP equivalents for women are 3 mmHg and 2 mmHg lower, respectively, than for age-matched men (see Appendix B).

Nocturnal dipping status
Physiologically, BP follows a diurnal pattern, with average night-time (asleep) BP levels substantially lower than daytime (awake) BP levels. There is wide inter-individual variation in the magnitude of the nightly BP dip. Night-time BP predicts end-organ damage and may be a better predictor of clinical outcomes than daytime BP. Night-time readings should be correlated with the patient’s diary to confirm their reliability.

Nocturnal non-dipping is defined as a fall of less than 10% in average night-time systolic or diastolic BP (or both), compared with daytime averages. Non-dipping (or nocturnal BP increase) suggests marked vascular organ damage or autonomic dysfunction.

Extreme dipping (> 20% reduction) may be associated with under-perfusion of the brain, particularly if antihypertensive treatment results in a greater fall.

Optimal BP control involves treating to targets for both daytime and night-time BP (e.g. a nightly dose of an antihypertensive drug may be indicated if non-dipping is detected).

Morning BP surge
The risk of stroke, sudden cardiac death or myocardial infarction is highest in the morning, during which there are increases in BP, heart rate, circulating catecholamines, other hormones and hypercoagulability. The magnitude and rate of morning BP surge is exaggerated in people with hypertension.

Morning systolic BP measured by ABP monitoring is a strong independent predictor of stroke and other CVD outcomes. Morning BP can also be measured using home BP measurement.

In older patients with hypertension, morning BP surge (difference between morning BP and nadir during sleep) measured by ABP monitoring is strongly correlated with the risk of stroke, independent of mean BP and nocturnal BP.

BP and heart rate variability
ABP monitoring provides information on:

- short-term BP and HR variability (standard deviation for daytime readings or night-time readings)
- circadian BP and HR variability (day–night difference)
- long-term BP and HR variability (when ABP monitoring repeated 6-monthly or yearly).
BP variability should be taken into account when interpreting BP profiles and assessing CVD and cerebrovascular risk, given evidence that the goals of treatment should include reduction of BP variability in addition to reduction of mean BP:

- Short-term night-time and daytime BP variability has been correlated with risk of end-organ damage and daytime systolic BP variability has been correlated with cardiovascular mortality risk.
- Daytime HR variability has been inversely correlated with cardiovascular mortality risk, and the co-occurrence of short-term high BP with low HR variability has been strongly correlated with cardiovascular mortality risk.
- Long-term (between-visit) clinic systolic BP variability in patients receiving antihypertensive treatment and maximum daytime ambulatory systolic BP are predictors of stroke risk, independent of mean systolic BP.

Therefore, BP variability may influence the choice of antihypertensive agent.

**BP load**

The proportion of time during which BP readings exceed hypertension threshold over a 24-hour period (i.e. 135/85 mmHg while awake and 120/75 mmHg during sleeping hours) can be defined as BP load. The measure is closely related to mean BP and BP variability and is a better predictor of end-organ damage than occasional clinic or mean ABP readings. An estimate of BP load (expressed as percentage time or area under the BP–time curve) is often provided automatically by ABP analysis software.

In a patient with an average 24-hour systolic BP of 120 mmHg, a BP load of approximately 20% would be expected. For an average 24-hour systolic BP of 130 mmHg, BP load would be approximately 50%, while for an average 24-hour systolic BP of 140 mmHg, BP load would be approximately 85%.

**Smoothness Index**

Smoothness Index is a measure of optimal 24-hour BP control based on ABP. It is defined as the ratio between the effect of treatment on average hourly BP for the 24-hour period (change in BP [$\Delta^H$]) and the standard deviation (SD) of the effect of treatment on average hourly BP (SD of average $\Delta^H$):

\[
\text{Smoothness Index} = \frac{\text{average } \Delta^H}{\text{SD of average } \Delta^H}
\]

Smoothness Index correlates with the effect of treatment on left ventricular hypertrophy more closely than the ratio of lowest BP to highest BP (trough : peak ratio).

Smoothness Index may indicate the intensity of BP lowering due to a larger numerator, as well as the effectiveness of 24-hour BP control.

**Ambulatory Arterial Stiffness Index**

Ambulatory Arterial Stiffness Index (AASI) is a measure of arterial wall stiffness, based on the concept that in stiffer vessels systolic BP will rise to a greater extent than diastolic BP as BP changes from lowest (sleeping) levels to highest daytime levels. AASI is best derived from 24-hour ABP monitoring.
It is calculated as one minus the regression slope of diastolic over systolic BP. Normal AASI is typically < 0.5 for younger adults and < 0.7 for older adults. AASI is correlated with other measures of arterial stiffness, is a better predictor of mortality than other risk factors, and is associated with subclinical organ damage in hypertensive patients irrespective of treatment. A symmetrical version of AASI has recently been developed to improve prediction of risk, independent of BP.

### Practical considerations

**Key points**

- Ideally, ABP monitoring should be performed by specialist monitoring centres.
- Only appropriately validated devices should be used for ABP monitoring.
- Arm circumference should be measured to select the correct cuff size.
- ABP readings may not be accurate when taken during exercise, movement or driving, or when the cardiac rate is irregular.

**Who should perform ABP monitoring?**

ABP monitoring is a specialised technique that requires staff training, skills and experience, validated and well-calibrated monitors, the use of correct cuff sizes and appropriate protocols. Ideally, it should be performed by experienced specialist monitoring centres that implement systems for quality control including continual training and assessment, calibration testing and regular evaluation of equipment.

**ABP monitoring devices**

ABP monitors use cuff oscillometry, which relies on detection of cuff pressure oscillations and defines the maximal oscillations as mean arterial BP and then uses an algorithm to calculate systolic and diastolic BP. Since different algorithms are used by different manufacturers, there is some variation between devices. Mean BP is the most reliable measurement by oscillometric devices. Studies assessing day-to-day variability in ABP profiles have generally reported good reproducibility.

Only devices validated and approved (reaching grade A) by international standards (British Hypertension Society or American Association for the Advancement of Medical Instrumentation) should be used for ABP monitoring. Lists of validated devices can be obtained from the websites of the European Society of Hypertension (ESH) and British Hypertension Society. Since the criteria specified in these protocols are difficult to fulfil, the Working Group on BP Monitoring of the ESH has developed a simplified protocol to facilitate validation of devices to be used in clinical practice.

**Importance of correct cuff size**

It is important to choose the correct cuff size, because BP obtained from oscillometric devices may vary, depending on cuff size and cuff-arm compliance. Selection of the correct cuff is aided by the manufacturer's labelling on the cuff and lines that indicate if the wrap-round is within the cuff's dimensions, but it is better to measure the arm.
circumference. People with a large upper arm (particularly obese people), may need conical-shaped cuffs.

**Assessing the quality of ABP data**

As a guide, a recording is usually considered successful when at least 85% of readings are suitable for analysis. ABP profiles should be interpreted cautiously, with reference to activity and sleep patterns.

ABP readings may not be accurate when taken during exercise, movement or driving, or when the cardiac rate is irregular (e.g. atrial fibrillation). Incorrect readings can be due to improper cuff fitting (e.g. patients with conical-shaped arms), movement artefact, tremor, weak or irregular pulse.

The best method for dealing with outlying values is a matter of considerable debate but, as a general rule, editing should be kept to a minimum, or the modified Casadei method used to eliminate artefactual readings. Some devices feature in-built actigraphy to detect movement, but these still need to be validated.

**Initial validation of readings in the clinic**

At the time the ABP monitoring device is fitted, at least three readings should be recorded simultaneously using a mercury column sphygmomanometer connected to the ABP monitoring device by a Y-connector. Average readings for ABP and sphygmomanometer should not differ by more than 5 mmHg.

**Frequency of measurements**

ABP monitoring devices are usually programmed to take readings at set intervals of 20–30 minutes during the day and night in order not to interfere activity or sleep, but measurements can be made more frequently; some centres use intervals of 15–20 minutes during the day and 30 minutes during the night, while others take readings at 30-minute intervals throughout the 24-hour period.

**Instructions for patients**

Patients should be given information and instructions about the procedure in order to minimise fear and anxiety, especially in nervous individuals. A written set of instructions to take home is recommended after the initial verbal description (in the patient’s first language, if possible). Patients should be informed which activities may interfere with the device and instructed to keep a diary to record timing of activities, sleep, taking of medicines, posture and symptoms (e.g. dizziness) that may be related to BP. A normal work day should be chosen rather than a rest day, to obtain a typical BP profile that better predicts end-organ damage.

While modern devices are quiet, lightweight and relatively easy to wear, inflation of the cuff may cause some minor discomfort, particularly in hypertensive subjects or when multiple repetitions of the reading are triggered due to errors in measurement. ABP monitoring is safe and not usually associated with complications, but occasionally petechiae of the upper arm or bruising under the inflating cuff may occur, and there may be sleep disturbances.
Key messages for patients

- The monitor will automatically inflate and record BP and HR periodically throughout the 24-hour period.
- Continue with typical daily activities throughout the monitoring period but avoid vigorous exercise during monitoring.
- When the cuff starts inflating, temporarily stop moving or talking for about 1 minute, keep the arm immobilised and relaxed, and try to relax and breathe normally.
- Some monitors give a warning tone prior to measurement.
- Do not kink tubing but do retighten connections if a leak occurs.
- Occasionally the device may repeat the measurement a moment later at a higher pressure. This is quite common and does not mean there is a problem.
- Keep the device on during sleep and do not switch it off.
- During monitoring, do not shower or bathe (sponge baths only) because the cuff should not be removed.
- Make diary entries as requested.
- Avoid napping during the day.
- Call phone number provided if you have technical difficulties during the monitoring period.

How often should ABP monitoring be repeated?

When and how often ABP monitoring is repeated depends on clinical judgement, and should take into consideration whether the person is at high risk of CVD and whether BP treatment targets have been met (Figure 2).

Repeated ABP monitoring should be considered to guide treatment in people with masked hypertension, ‘non-dippers’ and people with markedly increased BP variability.

Suspected white-coat hypertension should be confirmed by ABP monitoring repeated several weeks later. ABP monitoring (or home BP monitoring) should be repeated every 1–2 years in patients at low risk of CVD (Figure 1).

Future research

The potential benefits of normalisation of the circadian BP variability in people with hypertension, particularly by using chronotherapy aimed at optimising nocturnal BP, is not known. This issue is being investigated by long-term Ambulatory Blood Pressure Monitoring and Cardiovascular Events (MAPEC) study.

There is a need for randomised controlled studies comparing outcomes in patients with hypertension who are treated on the basis of ABP monitoring versus clinic BP measurements.

The ‘power’ of the morning BP surge is a mathematically derived measure of the morning rate–amplitude product. Currently, this parameter cannot readily be
calculated from data output provided by standard ABP analysis software. Power of the morning surge may become a useful standard diagnostic measure, because it has been shown to be almost doubled in people with hypertension or white-coat hypertension, compared with normotensive people.\textsuperscript{81}

**Acknowledgements**

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**Other contributors**

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Appendix A. Development process

This position statement was developed by an ad hoc working group of experts in the field of ABP monitoring and hypertension research under the auspices of the National Heart Foundation of Australia and the High Blood Pressure Research Council of Australia.

Taking as its starting point the Heart Foundation’s 2002 position statement, *Ambulatory blood pressure monitoring,*¹ the working group verified factual statements and revised the information to incorporate new evidence from reviews, clinical trials and controlled observational studies, including information from a large Australian ABP study that suggested new ABP equivalents for hypertension definitions and treatment targets should be adopted.

Consensus process

Each section was allocated to a subgroup of two working group members with particular expertise in the area. Subgroups reviewed published literature through database searches, hand-searching, personal knowledge and experience, and review of other guidelines for ABP monitoring. Drafts were circulated and reviewed by all working group members and discussed at a series of teleconferences held between [month] 2009 and November 2010 until consensus was reached.

The near final draft was circulated in November 2010 for external consultation by invited stakeholders including the following:

- [to be added at final draft].

Endorsements

This position statement has been endorsed by the National Heart Foundation of Australia and the High Blood Pressure Research Council of Australia.
Appendix B. Classification of BP levels

The cut-points for 'normal' BP (24-hour average <115/75 mmHg; daytime average <120/80 mmHg, night-time average <105/65 mmHg) are based on values identified in a large Australian study (rounded to 5 mmHg). These values agree closely with the findings of international studies (Table 4), which indicate that relative CVD risk associated with these levels is similar to relative CVD risk associated with clinic BP readings of <120/80 mg.

Diastolic BP cut-points in this position statement correspond exactly to those stated in European Society of Hypertension (ESH) recommendations for BP measurement. Systolic BP cut-points in this position statement are 10 mmHg lower than cut-points stated in ESH guidelines and American Heart Association guidelines.

ABP monitoring values adjusted for age and sex are shown in Table 5.

Table 4. Ambulatory and clinic BP equivalents from Australian and international studies

<table>
<thead>
<tr>
<th>Blood pressure (mmHg)</th>
<th>‘Normal’</th>
<th>Grade 1 (mild) hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinic BP*</td>
<td>&lt; 120/80</td>
<td>&gt; 140/90</td>
</tr>
<tr>
<td>Home BP</td>
<td>&lt; 120/80</td>
<td>&gt; 135/85</td>
</tr>
<tr>
<td>Predicted (seated clinic data)†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-hour</td>
<td>&lt; 117/76</td>
<td>≥ 133/84</td>
</tr>
<tr>
<td>Night</td>
<td>&lt; 102/67</td>
<td>≥ 121/76</td>
</tr>
<tr>
<td>Day</td>
<td>&lt; 120/78</td>
<td>≥ 136/87</td>
</tr>
<tr>
<td>Predicted (International outcome study)‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-hour</td>
<td>&lt; 117/74</td>
<td>≥ 131/79</td>
</tr>
<tr>
<td>Night</td>
<td>&lt; 101/65</td>
<td>≥ 120/71</td>
</tr>
<tr>
<td>Day</td>
<td>&lt; 121/79</td>
<td>≥ 138/86</td>
</tr>
<tr>
<td>ESH/AHA guidelines for ABP monitoring§</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-hour</td>
<td>&lt; 120/75</td>
<td>≥ 130/80</td>
</tr>
<tr>
<td>Night</td>
<td>&lt; 115/65</td>
<td>≥ 120/70</td>
</tr>
<tr>
<td>Day</td>
<td>&lt; 130/80</td>
<td>≥ 135/85</td>
</tr>
</tbody>
</table>

*Derived from Australian hypertension management guidelines
† ABP predicted from seated clinic BP (n = 5327)
‡ ABP predicted from International Database of Ambulatory Blood Pressure in relation to Cardiovascular Outcome (IDACO) study (n = 5682)
§ European Society for Hypertension and American Heart Association guidelines

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Table 5. Clinic BP thresholds and ABP equivalents according to age and sex

<table>
<thead>
<tr>
<th>Clinic BP threshold</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (years)</td>
<td>Age (years)</td>
</tr>
<tr>
<td></td>
<td>25–45</td>
<td>45–64</td>
</tr>
<tr>
<td>Grade 3 (severe) hypertension</td>
<td>180/110</td>
<td>176/104</td>
</tr>
<tr>
<td>Grade 2 (moderate) hypertension</td>
<td>160/100</td>
<td>158/96</td>
</tr>
<tr>
<td>Grade 1 (mild) hypertension</td>
<td>140/90</td>
<td>140/87</td>
</tr>
<tr>
<td>Target BP one associated condition*</td>
<td>130/80</td>
<td>131/79</td>
</tr>
<tr>
<td>Target BP proteinuria†</td>
<td>125/75</td>
<td>125/75</td>
</tr>
<tr>
<td>Normal BP</td>
<td>120/80</td>
<td>122/79</td>
</tr>
</tbody>
</table>

*People with any of the following: coronary heart disease, diabetes, chronic kidney disease, proteinuria (> 300 mg/day), stroke or transient ischaemic attack

† People with proteinuria (> 1 g/day)
References


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