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PEER REVIEWED FEATURE
2 CPD POINTS

Ambulatory blood pressure monitoring

Beyond the simple BP

Key points

- Ambulatory blood pressure monitoring (ABPM) is a useful tool in diagnosing and managing patients with an elevated clinic blood pressure (BP) reading.
- ABPM assesses a patient's BP more accurately than clinic measurements and provides additional key information about the patient's BP profile, including daytime (awake) and night-time (asleep) BP.
- ABPM can identify patients with masked hypertension (hypertension not detected by clinic BP measurements).
- Key results from ABPM must be identified to interpret a recording; these include the number of valid BP measurements, average daytime and night-time BPs, BP load and nocturnal dipping pattern.

PATRICK G. LAN MB BS, MClinEpidemiol, FRACP
ADRIAN G. GILLIN MB BS, PhD, FRACP

Ambulatory blood pressure monitoring (ABPM) is a vital tool in the diagnosis and management of hypertension. A systematic approach is required to properly interpret an ABPM recording.

The most recent UK guidelines from the National Institute for Health and Care Excellence (NICE) on the clinical management of primary hypertension in adults state that ambulatory blood pressure monitoring (ABPM) should be offered to all patients with a clinic blood pressure (BP) reading of 140/90 mmHg or higher.[1] Although no such recommendation currently exists in Australia, the Ambulatory Blood Pressure Monitoring Working Group (a subcommittee of the National Heart Foundation of Australia National Blood Pressure and Vascular Disease Advisory Committee and the High Blood Pressure Research Council of Australia) has formed the consensus view that ABPM provides 'considerable added value [on top of clinic BP] toward accurate diagnosis and the provision of optimal care' for patients with either suspected or true hypertension.[2] In addition, they have identified a number of patient groups for whom ABPM is indicated (Box).[2]

Unfortunately, ABPM remains underused in Australia. Possible reasons include the cost to patients, the limited availability of ABPM and the knowledge gap for many clinicians about interpreting an ABPM recording versus a clinic BP reading.

WHY PERFORM AN ABPM?

The Australian Ambulatory Blood Pressure Monitoring Working Group states that ABPM is indicated for a number of patient groups (Box).[2] However, ABPM should be considered for all patients who are being seen for assessment and management of their BP. The key

Dr Lan is a Research Fellow; and Professor Gillin is Clinical Associate Professor and Senior Staff Specialist in the Department of Renal Medicine, Royal Prince Alfred Hospital, Sydney, NSW.

CURRENT INDICATIONS FOR AMBULATORY BLOOD PRESSURE MONITORING[2]*

- Suspected white-coat effect
- Suspected masked hypertension
- Suspected lack of nocturnal dipping
- Elevated risk of future cardiovascular events
- Continued hypertension despite appropriate treatment
- Known or suspected episodic hypertension

*As suggested by the Ambulatory Blood Pressure Monitoring Working Group. Adapted from Head GA et al. J Hypertens 2012; 30: 253-266.

reasons for this are the limitations associated with clinic BP measurement. Clinic BP provides only a single snapshot of a patient's BP and is prone to errors.[3] In particular, it can be influenced by the white-coat effect. In contrast, ABPM can provide a profile of the patient's BP over 24 hours, and its results have been found to correlate better with cardiovascular outcomes in both the general and hypertensive populations.[4-6]

ABPM VERSUS HOME BP MEASUREMENT

An alternative means of obtaining a nonclinic BP is by home BP measurement. This has advantages over ABPM as it is cheaper and less onerous on the patient and can be performed by patients themselves. However, it is essential that a validated device is used.[7,8] Patients must also be appropriately educated as to how to take readings. In regards to when to take readings, the European Society of Hypertension has suggested that two measurements be taken both in the morning and the evening for at least three to four days.[8]

At present, opinions differ as to whether home BP measurement is as effective as ABPM. A number of studies have found home BP measurement to be as effective as ABPM in identifying prognosis, but other studies have found home BP to be inferior to ABPM.[9-12] Overall, both home BP measurement and ABPM have roles in the diagnosis and management of hypertension, which may be complementary.

STEPS IN INTERPRETING AN AMBULATORY BLOOD PRESSURE RECORDING

Patient undergoes ambulatory blood pressure monitoring (ABPM)

↓

Is the ABPM satisfactory?
- >14 daytime readings and >7 night-time readings, and
- >70 to 85% of readings are valid

↓

Assess average BP levels compared with ABPM hypertension thresholds; a level exceeding any one of the following is classed as hypertension:
- 24-hour average ≥130/80 mmHg
- daytime average ≥135/85 mmHg
- night-time average ≥120/70 mmHg

↓

Assess BP load (percentage of readings above hypertension threshold)
- Ideally, BP load <20%

↓

Assess nocturnal dipping
- Nondipper: <10%
- Normal: 10 to 20%
- Extreme dipper: >20%

HOW IS ABPM PERFORMED?

ABPM must be performed using a validated BP monitor, and a list of these is available from the British Hypertension Society (www.bhsoc.org).[7] Most monitors utilise the oscillometric method of measuring BP, with the cuff usually worn on the patient's nondominant arm. It is essential to ensure the correct-sized cuff is used, and an initial reading is performed and compared with a measurement obtained from a calibrated sphygmomanometer at the clinic. The patient should be advised to keep their arm still whenever the cuff inflates, and should be provided with an information sheet that explains, for example, how to remove and turn off the device if they are unable to complete the recording.

TABLE 1. RELATION BETWEEN CLINIC AND AMBULATORY BLOOD PRESSURE THRESHOLDS

		Ambulatory BP equivalents (mmHg)		
	Clinic BP (mmHg)	24-hour average	Daytime average	Night-time average
Normal range	<120/80	<115/75	<120/80	<105/65
Hypertension threshold	140/90	130/80	135/85	120/70

ABBREVIATION: BP = blood pressure. Adapted from Head et al. J Hypertens 2012; 30: 253-266.[2]

Readings are usually taken over a 24-hour period, and can be performed up to every 15 minutes when the patient is awake, and up to every 30 minutes when they are asleep.[2,8] ABPM should be undertaken during a normal 'working' day for the patient, and they should keep a diary of the day's activities, including the time of any medications, exercise and when they went to bed.

HOW TO INTERPRET AN ABPM

As ABPM yields multiple BP readings, it can provide the clinician with information beyond simple BP measurement. This includes average BP readings over the time of measurement. It must be remembered that the threshold values for hypertension on ABPM are lower than those for clinic BP readings (see Table 1).

As a significant amount of information is provided, the interpretation of an ABPM record can be difficult and requires a considered approach. A suggested approach to interpretation is shown in the flowchart. A sample ABPM report for Patient X is summarised in Figures 1 and 2 and Table 2.

Is the ABPM satisfactory?

The first question that needs to be answered is whether the ABPM has been carried out satisfactorily, which is determined by:

- the number of BP readings during both the daytime and night-time
- the percentage of readings which have been performed successfully.

There is no single international protocol stating how often BP should be measured during an ABPM, with readings being carried out up to every 15 minutes when the patient is awake, and up to every 30 minutes when they are asleep.[2,8] However, it has been recognised that more than 14 BP measurements are required during the day and more than seven are required at night for the ABPM to be considered satisfactory.[13]

In addition, the percentage of successful readings must be assessed. There is also no international consensus on the minimum percentage of successful readings required for the ABPM to be considered satisfactory. However, current guidelines suggest that if more than 70 to 85% of attempts result in a successful reading then the recording should be considered satisfactory.[2,8] Unsuccessful ('error') readings can result from a movement artefact, systolic BP outside the device's range, significant variation in the pulse rate and low battery/power.

Figure 2 shows the ABPM readout for Patient X, which can be considered satisfactory. A total of 39 valid BP measurements were obtained with one invalid (error) measurement, giving a success rate of 97.5%. Valid measurements comprised 31 taken during the day (awake) and eight measurements taken at night (asleep).

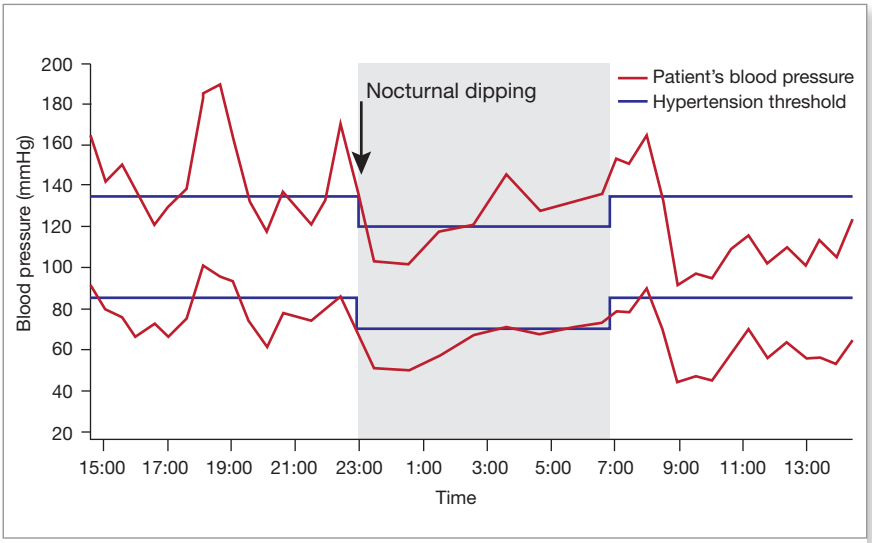

Figure 1. Ambulatory blood pressure recording for Patient X (red lines) compared with systolic and diastolic thresholds for hypertension (blue lines). Multiple patient readings during both the day and night are above the respective hypertension thresholds. Nocturnal dipping is seen, with night-time BP measurements taken after 23:00 being slightly lower than those taken before 23:00. However, overall the patient is a 'nondipper'.

Nr.		Date & Time	Syst.	MAP	Diast.	HR	PP	RPP	Comment
1		16/10/2013 2:38:00	**164**	118	**92**	65	72	10660	Manual measurement
2		16/10/2013 3:03:00	**142**	103	80	64	62	9088	
3		16/10/2013 3:35:00	**151**	105	76	61	75	9211	
4		16/10/2013 4:00:00	**137**	90	66	59	71	8083	
5		16/10/2013 4:36:00	121	89	73	58	48	7018	
6		16/10/2013 5:01:00	130	91	66	56	64	7280	
7		16/10/2013 5:35:00	**139**	98	75	55	64	7645	
8		16/10/2013 6:07:00	**186**	137	**101**	59	85	10974	
9		16/10/2013 6:39:00	**190**	130	**96**	61	94	11590	
10		16/10/2013 7:04:00	**163**	120	**93**	59	70	9617	
11		16/10/2013 7:35:00	133	98	73	56	60	7448	
12		16/10/2013 8:07:00	117	82	61	55	56	6435	
13		16/10/2013 8:35:00	**137**	101	78	53	59	7261	
Event		16/10/2013 9:05:00							Error measurement (nr. 3)
14		16/10/2013 9:31:00	121	90	74	54	47	6534	
15		16/10/2013 9:56:00	134	102	80	53	54	7102	
16		16/10/2013 10:24:00	**171**	113	**86**	54	85	9234	
17	☽	16/10/2013 11:28:00	103	69	51	52	52	5356	
18	☽	17/10/2013 12:33:00	102	68	50	52	52	5304	
19	☽	17/10/2013 1:31:00	118	78	57	53	61	6254	
20	☽	17/10/2013 2:33:00	**121**	86	67	57	54	6897	
21	☽	17/10/2013 3:37:00	**146**	98	**71**	57	75	8322	
22	☽	17/10/2013 4:40:00	**128**	89	68	50	60	6400	
23	☽	17/10/2013 5:44:00	**132**	93	**71**	51	61	6732	
24	☽	17/10/2013 6:35:00	**136**	94	**73**	49	63	6664	
25		17/10/2013 7:02:00	**154**	106	79	50	75	7700	
26		17/10/2013 7:27:00	**151**	103	78	52	73	7852	
27		17/10/2013 7:59:00	**165**	118	**90**	55	75	9075	
28		17/10/2013 8:32:00	133	91	69	54	64	7182	
29		17/10/2013 8:59:00	91	59	44	62	47	5642	
30		17/10/2013 9:32:00	97	63	47	53	50	5141	
31		17/10/2013 10:04:00	95	61	45	52	50	4940	
32		17/10/2013 10:39:00	109	74	58	56	51	6104	
33		17/10/2013 11:11:00	116	85	70	59	46	6844	
34		17/10/2013 11:48:00	102	71	56	61	46	6222	
35		17/10/2013 12:23:00	110	80	64	60	46	6600	
36		17/10/2013 12:58:00	101	71	56	62	45	6262	
37		17/10/2013 1:25:00	114	74	56	65	58	7410	
38		17/10/2013 1:55:00	105	70	53	66	52	6930	
39		17/10/2013 2:24:00	124	88	65	64	59	7936	

Figure 2. Ambulatory blood pressure monitoring readout for Patient X.

ABBREVIATIONS: Diast = diastolic; HR = heart rate; MAP = mean arterial pressure; PP = pulse pressure; RPP = rate pressure product; Syst = systolic.

Readings should be interpreted alongside the patient's diary as exercise results in higher BP readings. Elevated BP readings associated with exercise do not require clinical intervention.

Average blood pressure

Secondly, the average BP readings should be assessed by comparison with the ABPM thresholds for hypertension (Box 1). As an ABPM is performed outside the clinic, it can identify patients with white-coat hypertension or masked hypertension. White-coat hypertension is a well-recognised phenomenon where the clinic BP meets the criteria for hypertension, but BP readings obtained either at home or by ABPM are normal.[2]

On the other hand, masked hypertension is a relatively new diagnosis gaining increasing attention. Patients with masked hypertension are those who have a clinic BP reading below the threshold for hypertension but are found to have hypertension on ABPM or home BP measurement. Patients with an increased likelihood of masked hypertension include those with obstructive sleep apnoea, chronic kidney disease, evidence of target organ damage despite a normal clinic BP reading and those with a family history of hypertension.[2] Masked hypertension is estimated to affect up to 10% of the general population.[14] Patients can be classified according to the pattern of hypertension found on ABPM, such as morning hypertension, daytime hypertension or night-time hypertension.[15]

Although there has been limited clinical research assessing the outcomes of treatment in patients with masked hypertension, there is a strong argument that they should receive antihypertensive therapy.[16] The main problem in treating this group is assessing their response to therapy, which requires further ABPM.

Table 2 summarises the ABPM findings for Patient X. This reveals that the overall and daytime average BP levels did not exceed their respective thresholds for hypertension, but that the nocturnal average systolic BP was above the nocturnal threshold (120 mmHg). This is an example of a patient with masked hypertension, given that the clinic BP would most likely have been normal.

Blood pressure load

The patient's BP load should be assessed next, defined as the percentage of time that the BP readings exceeded the hypertension threshold during the 24 hours (that is, were more than 135/85 mmHg during the day and more than 120/80 mmHg during the night).[17] The BP load is very closely related to the average BP. Ideally, the BP load should be less than 20%. The BP load has been found to better predict end-organ damage than a clinic BP measurement.[18]

The BP load is a useful parameter to consider especially in patients with treated hypertension, and if elevated may suggest a need to increase antihypertensive treatment despite a normal average BP on ABPM. For a nonhypertensive patient, the significance of a BP load over 20% is uncertain, but it may indicate a need to ensure basic lifestyle interventions are implemented, with close follow up of BP.

TABLE 2. SUMMARY OF AMBULATORY BLOOD PRESSURE MONITORING FOR PATIENT X

	Overall	Awake	Asleep
General			
Number of measurements	39	31	8
Total time	23:46:00	16:12:00	07:34:00
Average	130/69 mmHg	132/71 mmHg	123/64 mmHg
SD	24.9/14.3 mmHg	26.6/15.1 mmHg	15.5/9.4 mmHg
Pulse pressure	61.1 mmHg	61.4 mmHg	59.8 mmHg
Systolic			
Number of measurements	20 (51%) ≥130 mmHg	13 (42%) ≥35 mmHg	5 (63%) ≥120 mmHg
Maximum	190 mmHg at 18:39	190 mmHg at 18:39	146 mmHg at 03:37
Minimum	91 mmHg at 08:59	91 mmHg at 08:59	102 mmHg at 0:33
Diastolic			
Number of measurements	8 (21%) ≥80 mmHg	8 (19%) ≥85 mmHg	3 (38%) ≥70 mmHg
Maximum	101 mmHg at 18:07	101 mmHg at 18:07	73 mmHg at 06:35
Minimum	44 mmHg at 08:59	44 mmHg at 08:59	50 mmHg at 0:33
Heart rate			
Average	57 bpm	58 bpm	53 bpm
SD	4.7 bpm	4.5 bpm	3.0 bpm
Maximum	66 bpm at 13:55	66 bpm at 13:55	57 bpm at 02:33
Minimum	49 bpm at 06:35	50 bpm at 07:02	49 bpm at 06:35
Nocturnal dipping, early morning surge			
Decrease in BP when asleep	6.9%/10.5% (not a dipper)		
Morning average	156.7/82.3 mmHg		

ABBREVIATIONS: bpm = beats per minute; SD = standard deviation.

Table 2 shows that the BP load for Patient X is more than 20%, given that the proportion of BP readings above the hypertension threshold was 42% for daytime systolic BP, 63% for night-time systolic BP and 38% for night-time diastolic BP. The BP load was less than 20% only for daytime diastolic BP (19%).

Dipper or nondipper?

There is normally a diurnal variation in BP, with BP being lower at night than during the day, known as 'dipping'. The ABPM report should be assessed for nocturnal nondipping, defined as a fall of less than 10% in either the average systolic BP or the average diastolic BP at night compared with their respective daytime averages.[2]

Suggested causes of nondipping are both intrinsic and extrinsic. They include hormonal and metabolic factors such as increased sympathetic activation of the autonomic nervous system and hypothyroidism, various disease states

including diabetes mellitus, obesity, sleep apnoea and chronic kidney disease, and factors such as ageing and smoking.[19]

Nondipping may indicate the presence of end-organ damage and is associated with a higher risk of future cardiovascular events.[20,21] This finding has led to research that focuses on tailoring antihypertensive treatment so as to mirror the normal circadian BP pattern.[22,23] Current results suggest that there may be some benefit from nocturnal dosing of therapy in an attempt to achieve the normal diurnal pattern of BP in hypertensive patients. In contrast, some patients show extreme dipping – more than 20%.[2] The clinical significance of extreme dipping is currently not well understood.

Table 2 shows that Patient X is a nondipper as his average systolic BP fell less than 10% (6.9%) during the night.

Special considerations

In certain patient groups, different BP thresholds for treatment may need to be considered for ABPM. These groups include children and adolescents, pregnant women and patients receiving haemodialysis or peritoneal dialysis.

CONCLUSION

ABPM provides clinicians with important information about the patient's BP profile, which can be used to guide future management. It should be considered in all patients with an elevated or borderline clinic BP reading. MT

REFERENCES

A list of references is included in the website version (www.medicinetoday.com.au) and the iPad app version of this article.

COMPETING INTERESTS: None.

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PATRICK G. LAN MB BS, MClinEpidemiol, FRACP; **ADRIAN G. GILLIN** MB BS, PhD, FRACP

REFERENCES

1. National Clinical Guideline Centre (UK). Hypertension: the clinical management of primary hypertension in adults. NICE clinical guidelines, no. 127. London: Royal College of Physicians (UK); 2011.
2. Head GA, McGrath BP, Mihailidou AS, et al. Ambulatory blood pressure monitoring in Australia: 2011 consensus position statement. J Hypertens 2012; 30: 253-266.
3. Pickering TG. The role of ambulatory monitoring in reducing the errors associated with blood pressure measurement. Herz 1989; 14: 214-220.
4. Verdecchia P, Porcellati C, Schillaci G, et al. Ambulatory blood pressure: an independent predictor of prognosis in essential hypertension. Hypertension 1994; 24: 793-804.
5. Sega R, Facchetti R, Bombelli M, et al. Prognostic value of ambulatory and home blood pressures compared with office blood pressure in the general population: follow-up results from the Pressioni Arteriose Monitorate e Loro Associazoni (PAMELA) study. Circulation 2005; 111: 1777-1783.
6. Clement DL, De Buyzere ML, De Bacquer DA, et al. Prognostic value of ambulatory blood-pressure recordings in patients with treated hypertension. N Engl J Med 2003; 348: 2407-2415.
7. British Hypertension Society. Blood pressure monitors validated for clinical use. Available online at: www.bhsoc.org/bp-monitors/bp-monitors/ (accessed April 2014).
8. Mancia G, Fagard R, Narkiewicz K, et al. 2013 ESH/ESC guidelines for the management of arterial hypertension: the Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Eur Heart J 2013; 34: 2159-2219.
9. Fagard RH, Van Den Broeke C, De Cort P, et al. Prognostic significance of blood pressure measured in the office, at home and during ambulatory monitoring in older patients in general practice. J Hum Hypertens 2005; 19: 801-807.
10. Mancia G, Facchetti R, Bombelli M, et al. Long-term risk of mortality associated with selective and combined elevation in office, home and ambulatory blood pressure. Hypertension 2006; 47: 846-853.
11. Hodgkinson J, Mant J, Martin U, et al. Relative effectiveness of clinic and home blood pressure monitoring compared with ambulatory blood pressure monitoring in diagnosis of hypertension: systematic review. BMJ 2011; 342: d3621.
12. Hara A, Tanaka K, Ohkubo T, et al. Ambulatory versus home versus clinic blood pressure. The association with subclinical cerebrovascular diseases: the Ohasama Study. Hypertension 2012; 59: 22-28.
13. O'Brien E, Coats A, Owens P, et al. Use and interpretation of ambulatory blood pressure monitoring: recommendations of the British Hypertension Society. BMJ 2000; 320: 1128.
14. Pickering TG, Eguchi K, Kario K. Masked hypertension: a review. Hypertension Res 2007; 30: 479-488.
15. Kawano Y, Horio T, Matayoshi T, et al. Masked hypertension: subtypes and target organ damage. Clin Exp Hypertens 2008; 30: 289-296.
16. Ogedegbe G, Agyemang C, Ravenell JE. Masked hypertension: evidence of the need to treat. Curr Hypertens Rep 2010; 12: 349-355.
17. Head GA, McGrath BP, Mihailidou AS, et al. Ambulatory blood pressure monitoring. Aust Fam Phys 2011; 40: 877-880.
18. White WB. Blood pressure load and target organ effects in patients with essential hypertension. J Hypertens Suppl 1991; 9: S39-S41.
19. Kanbay M, Turgut F, Uyar ME, Akcay A, Covic A. Causes and mechanisms of nondipping hypertension. Clin Exp Hypertens 2008; 30: 585-597.
20. Verdecchia P, Clement D, Fagard R, Palatini P, Parati G. Blood pressure monitoring. Task force III: target-organ damage, morbidity and mortality. Blood Press Monit 1999; 4: 303-317.
21. Verdecchia P, Porcellati C, Schillaci G, et al. Ambulatory blood pressure. An independent predictor of prognosis in essential hypertension. Hypertension 1994; 24: 793-801.
22. Hermida RC, Ayala DE, Mojon A, et al. Influence of circadian time of hypertension treatment on cardiovascular risk: results of the MAPEC study. Chronobiol Int 2010; 27: 1629-1651.
23. Hermida RC, Ayala DE, Mogon AE, et al. Bedtime dosing of antihypertensive medications reduces cardiovascular risk in CKD. J Am Soc Nephrol 2011; 22: 2313-2321.