The use of ambulatory blood pressure measurement

Measurement of ambulatory blood pressure is recommended by the National Institute for Health and Care Excellence guidelines to confirm the diagnosis of hypertension in the UK. This article describes the use of ambulatory devices, and discusses the benefits and disadvantages of their use in clinical practice.

Hypertension is a major cause of morbidity and mortality worldwide (Lim et al, 2012) and high blood pressure is a key risk factor for the development of cardiovascular disease (Lewington et al, 2002) by increasing the risk of myocardial infarction, stroke, congestive heart failure and atherosclerosis. Accuracy in measuring blood pressure is fundamental to the correct diagnosis and good management of hypertension.

Blood pressure is not static but undergoes natural variations from one heartbeat to another and varies in a circadian fashion throughout the day. This is dependent upon a number of factors including stress, nutritional factors, drugs, disease, exercise and position. Therefore, any single reading represents only a snapshot of a much wider range of blood pressure values that a person has experienced during a given period. Repeated measurement therefore allows better estimation of the underlying blood pressure.

What is ambulatory blood pressure measurement?

Ambulatory blood pressure measurement is a non-invasive method of obtaining blood pressure readings at regular intervals over 24 hours, while the patient is in his/her own environment, undertaking his/her usual activities. It was first developed in the 1960s (Kain et al, 1964). Initially patients had to inflate the device manually so night-time readings were not possible. However, subsequently automated brachial artery measurements over 24 hours became possible.

What does ambulatory blood pressure measurement involve?

A cuff connected to a portable electronic monitor is worn continuously by the patient for a period of 24 hours. The cuff is set to inflate at least twice an hour during waking hours (typically 8:00 to 22:00) and once an hour overnight (22:00 to 8:00). Average daytime blood pressure (calculated from at least 14 daytime readings) is used to diagnose hypertension (National Institute for Health and Clinical Excellence, 2011).

Careful fitting of these devices is essential for patient comfort and accurate readings, and all health-care professionals should undergo training and be assessed as competent in the skill. A full assessment should be undertaken before the ambulatory blood pressure measurement is fitted. Blood pressure should be taken on both arms. The cuff is then placed next to the skin on the non-dominant arm unless there is a significant inter-arm difference in the blood pressure (suggested as >10 mmHg by Clark et al, 2012), when it should be placed on the arm with the highest blood pressure.

Patients taking anticoagulant therapy or with fragile skin should be assessed for appropriateness, as continual monitoring may lead to localized bruising or compromise skin integrity. The presence of a hemiparesis or any other long-standing injury to the arm selected for ambulatory blood pressure measurement, as well as a history of mastectomy, nodal clearance or lymphoedema on the selected side, needs to be assessed and measurements taken on the unaffected side. It is also important to assess the patient's general mental health status, or the presence of any learning difficulties or behavioural characteristics which may make ambulatory blood pressure measurement an unsafe procedure. Ambulatory blood pressure measurement may be an uncomfortable experience, but it should not be painful. Patients should be instructed to remove the monitor if experiencing pain or obvious injury during the monitoring period. A local information sheet with contact telephone numbers should be devised.

It is important to ensure that the correct cuff size is used to maximize comfort and accuracy of the readings. Mid arm circumference should be measured and appropriate small, adult, large or extra-large cuff selected. The

Dr James A Hodgkinson *is Research Fellow in Primary Care Clinical Sciences, University of Birmingham, Birmingham,* **Dr Katherine L Tucker** *is Senior Researcher in the Department of Primary Care Health Sciences, University of Oxford, Oxford,* **Professor Una Martin** *is Reader in Clinical Pharmacology and Lead for Hypertension Service in the School of Clinical and Experimental Medicine, University of Birmingham, Birmingham,* **Mrs Louise Beesley** *is Clinical Nurse Specialist in Hypertension at Queen Elizabeth Hospital, Queen Elizabeth Medical Centre, Birmingham and* **Professor Richard J McManus** *is Professor of Primary Care and General Practitioner in the Department of Primary Care Health Sciences, University of Oxford, Oxford OX2 6GG*

Correspondence to: Professor RJ McManus (richard.mcmanus@phc.ox.ac.uk)

© 2015 MA Healthcare Ltd

cable is then threaded across the patient's shoulders and down to the monitor on his/her opposite hip: this can be attached to a belt or harness.

Patients should be instructed to undertake their normal activities, with consideration of health and safety restrictions if worn at work. It is also advisable to limit cardiovascular exercise during the monitoring period to avoid multiple physiologically high blood pressure measurements in response to exercise. Patients should be advised that driving should be avoided or kept to a minimum throughout the monitoring period. If driving is unavoidable, patients should be shown how to switch the monitor off before starting their journey and switch it back on when they have arrived at their destination. Most devices will give a 5-second warning sound before inflation and patients should be instructed to either sit down or stand still when this occurs in anticipation of a reading being taken. Patients should remain still and not talk, with the arm supported during measurement. If worn overnight, the monitor should be placed under a pillow or to the patient's side while the cuff remains in situ.

After the 24-hour period has elapsed the patient returns the device to the surgery or clinic. Thereafter, stored readings are downloaded via a computer package. These are usually displayed in both graphical and tabulated format, with the mean 24-hour, daytime and night time readings given. Examples of the output from an ambulatory monitor are shown in *Figure 1*.

Analyses and interpretation of ambulatory blood pressure measurement results require proper training (Hermida et al, 2013), and one guideline suggests that, while a nurse with experience in hypertension can master the use of ambulatory blood pressure measurement devices after brief training, interpretation of ambulatory blood pressure measurement profiles requires specific experience in the technique best provided by the doctor in charge of an ambulatory blood pressure measurement service (O'Brien et al, 2013). Clinical core competency requirements for ambulatory blood pressure measurement do not currently exist, although they have been proposed (Shimbo et al, 2015). Various criteria have been suggested to determine if an ambulatory blood pressure measurement data series is valid, but none is considered a gold standard. Some guidelines suggest that if over 30% of scheduled measurements are missing then the data is invalid (Hermida et al, 2013; O'Brien et al, 2013) but others suggest 20% or focus on the total number of readings available (variously at least 10, 14 or 20 in the daytime) (Shimbo et al, 2015).

One guideline suggests ambulatory blood pressure measurement should ideally be performed for two consecutive 24-hour periods (i.e. 48 hours in total) (Hermida et al, 2013) to maximize the validity and reproducibility of blood pressure values, but this should certainly not be considered a requirement.

It is important to consider practical issues relating to ambulatory blood pressure measurement. Cuffs and pouches should be laundered between every use, according to local policy. Battery life also needs to be monitored and batteries changed following a set number of uses to avoid failure while on a patient.

Interpretation of ambulatory blood pressure measurement

In order to compare to clinic blood pressure readings, mean daytime systolic blood pressure has to be adjusted upward by 5–10 mmHg and mean daytime diastolic blood pressure has to be adjusted upward by 5 mmHg, but this assumed difference can vary considerably and is usually greater in people with a higher baseline blood pressure and as people age (see below for influence on diagnostic thresholds). Maintaining a diary of events during ambulatory blood pressure measurement is useful, and it is best practice to ask patients to keep a sleep diary specifying the time that they went to bed and awoke, including daytime sleep if present. The average awake ambulatory blood pressure can then be used, calculated according to the record kept by each patient.

In the diagnosis of hypertension, the most recent National Institute for Health and Clinical Excellence (2011) guidelines recommend use of the following thresholds and measurement techniques:

- Stage 1 hypertension: initial clinic blood pressure 140/90 mmHg or higher and subsequent ambulatory blood pressure measurement daytime average or home blood pressure average blood pressure 135/85 mmHg or higher
- Stage 2 hypertension: initial clinic blood pressure 160/100 mmHg or higher and subsequent ambulatory blood pressure measurement daytime average or home blood pressure average blood pressure 150/95 mmHg or higher.

What can ambulatory blood pressure measurement be used for?

Ambulatory blood pressure monitoring is typically used where there is uncertainty in diagnosis, resistance to treatment, to determine diurnal variation, or concerns about variability and 'white coat' effect (Redon et al, 1998; Verdecchia, 2001; Whitworth and World Health Organization, International Society of Hypertension Writing Group, 2003; Mancia et al, 2013). It has therefore arguably become the de facto reference standard for the diagnosis of hypertension (Hodgkinson et al, 2011a).

Ambulatory blood pressure measurement, like other out-of-office measurements, is believed to reduce the white coat effect, in which a patient's blood pressure is elevated during the examination process as a result of the stress of being in a medical situation (Verdecchia et al, 2004).

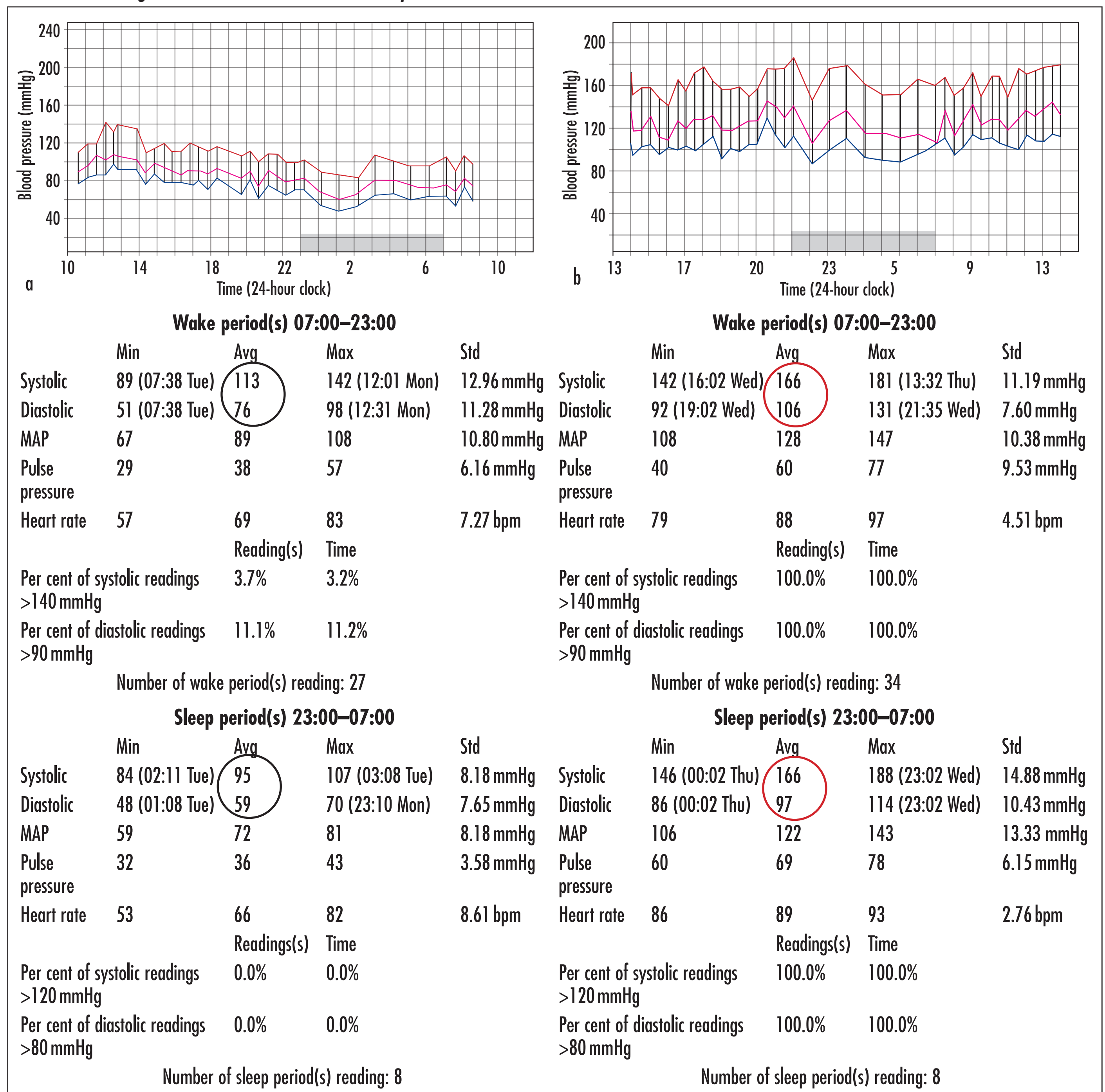
A major advantage of ambulatory blood pressure measurement is that it provides more information than either home or clinic blood pressure measurements because more readings are taken. Clinic blood pressure measure-

© 2015 MA Healthcare Ltd

ments in particular are fewer in number, and so more subject to general variability including regression to the mean. 24-hour ambulatory blood pressure measurement allows estimates of increased cardiac risk including excessive blood pressure variability or failure to reduce blood pressure nocturnally. Blood pressure variability is recognized as a key element in subsequent risk of cardiovascular disease and stroke in particular (Rothwell, 2010). However, while some antihypertensives affect variability more than others (Webb et al, 2010), it is not yet clear how measurement of variability can be incorporated in clinical management.

In addition, only ambulatory blood pressure measurement can determine night-time dipping patterns, which have important prognostic implications. Ambulatory blood pressure measurement allows blood pressure to be intermittently monitored during sleep, and is useful to determine whether the patient is a dipper or non-dipper,

Figure 1. Examples of 24-hour measurement of ambulatory blood pressure, recorded using an ambulatory blood pressure measurement monitor. Readings from (a) a normotensive individual with the average systolic and diastolic readings circled in black and (b) from a hypertensive individual with the average systolic and diastolic readings circled in red. MAP = mean arterial pressure.



(a) Wake period(s) 07:00–23:00

	Min	Avg	Max	Std
Systolic	89 (07:38 Tue)	113	142 (12:01 Mon)	12.96 mmHg
Diastolic	51 (07:38 Tue)	76	98 (12:31 Mon)	11.28 mmHg
MAP	67	89	108	10.80 mmHg
Pulse pressure	29	38	57	6.16 mmHg
Heart rate	57	69	83	7.27 bpm
		Reading(s)	Time	
Per cent of systolic readings >140 mmHg		3.7%	3.2%	
Per cent of diastolic readings >90 mmHg		11.1%	11.2%	

Number of wake period(s) reading: 27

(a) Sleep period(s) 23:00–07:00

	Min	Avg	Max	Std
Systolic	84 (02:11 Tue)	95	107 (03:08 Tue)	8.18 mmHg
Diastolic	48 (01:08 Tue)	59	70 (23:10 Mon)	7.65 mmHg
MAP	59	72	81	8.18 mmHg
Pulse pressure	32	36	43	3.58 mmHg
Heart rate	53	66	82	8.61 bpm
		Readings(s)	Time	
Per cent of systolic readings >120 mmHg		0.0%	0.0%	
Per cent of diastolic readings >80 mmHg		0.0%	0.0%	

Number of sleep period(s) reading: 8

(b) Wake period(s) 07:00–23:00

	Min	Avg	Max	Std
Systolic	142 (16:02 Wed)	166	181 (13:32 Thu)	11.19 mmHg
Diastolic	92 (19:02 Wed)	106	131 (21:35 Wed)	7.60 mmHg
MAP	108	128	147	10.38 mmHg
Pulse pressure	40	60	77	9.53 mmHg
Heart rate	79	88	97	4.51 bpm
		Reading(s)	Time	
Per cent of systolic readings >140 mmHg		100.0%	100.0%	
Per cent of diastolic readings >90 mmHg		100.0%	100.0%	

Number of wake period(s) reading: 34

(b) Sleep period(s) 23:00–07:00

	Min	Avg	Max	Std
Systolic	146 (00:02 Thu)	166	188 (23:02 Wed)	14.88 mmHg
Diastolic	86 (00:02 Thu)	97	114 (23:02 Wed)	10.43 mmHg
MAP	106	122	143	13.33 mmHg
Pulse pressure	60	69	78	6.15 mmHg
Heart rate	86	89	93	2.76 bpm
		Readings(s)	Time	
Per cent of systolic readings >120 mmHg		100.0%	100.0%	
Per cent of diastolic readings >80 mmHg		100.0%	100.0%	

Number of sleep period(s) reading: 8

© 2015 MA Healthcare Ltd

i.e. whether or not blood pressure falls at night compared to daytime values. Absence of a night-time dip is associated with poorer health outcomes, including increased mortality (Minutolo et al, 2011).

The exaggerated morning surge in blood pressure is thought to be a risk factor for wake up stroke (which is implicated in up to 27% of all ischaemic strokes; Fink et al, 2002) and indeed other cardiovascular events that occur in the morning hours (Kario and White, 2008; Kario, 2010; White, 2010). Morning surge in blood pressure is commonly assessed by ambulatory blood pressure measurement and defined as the sleep–trough surge, calculated by subtracting the morning blood pressure (mean of four readings over 2 hours just after wake-up) from the lowest nocturnal blood pressure (mean of three readings centred around the lowest night time blood pressure) (Kario et al, 2003; Kario, 2010). However, there are several alternative definitions but only ambulatory blood pressure measurement can measure the sleep–trough surge, prewaking surge or rising blood pressure surge that has been shown to coincide with acute cardiovascular events, such as myocardial infarction, stroke, sudden cardiac death and ischaemic episodes.

Why is ambulatory blood pressure measurement particularly important now?

Initial management of hypertension has conventionally required a diagnosis based on several elevated clinic or office blood pressure measurements (U.S. Department of Health and Human Services, 2004; Williams et al, 2004; National Collaborating Centre for Chronic Conditions, 2006; National Institute for Health and Clinical Excellence, 2006). Even in the infancy of ambulatory blood pressure measurement, early evidence found ambulatory blood pressure correlated with target organ damage. Now it is acknowledged that ambulatory blood pressure measurement not only estimates 'true' mean blood pressure more accurately than clinic measurement, because multiple readings are taken, but that it has better correlation with a range of cardiovascular outcomes and end organ damage (Imai et al, 1996; Fagard et al, 1997; Mancia et al, 1997; Staessen et al, 1999; Ohkubo et al, 2000; Verdecchia, 2000). This prognostic superiority has been demonstrated in both genders, in young and old, in treated and untreated hypertensives, in obese patients, in patients at high risk, and in those with cardiovascular or renal disease, as well as the general population (Boggia et al, 2007; Fagard et al, 2008a,b; Minutolo et al, 2011; de la Sierra et al, 2012; Palatini et al, 2015), although these studies were necessarily undertaken using monitors not specifically validated for use in these special populations.

The benefits of out-of-office techniques, in particular ambulatory blood pressure measurement, include the correct diagnosis of white coat hypertension and improved diagnostic accuracy. Indeed, the weight of evidence suggests that ambulatory blood pressure measurement is the best prognostic indicator, followed by home blood pressure monitoring, and then clinic blood pressure monitoring. Thus ambulatory blood pressure measurement is best able to predict those patients who require treatment. Its greater use should result in improved outcomes for patients and lower costs to the NHS through reduced antihypertensive prescribing and better targeting resulting in fewer cardiovascular events. Furthermore, out-of-office methods can enable a diagnosis to be made more quickly.

A possible objection is that ambulatory monitors are more expensive than those used in the home or clinic setting with a median NHS cost of around £1000 (Lovibond et al, 2011). However, a systematic review (Hodgkinson et al, 2011a) and cost-effectiveness study (Lovibond et al, 2011) found ambulatory blood pressure measurement is more accurate than both clinic and home monitoring in diagnosing hypertension and that a diagnostic strategy for hypertension using ambulatory monitoring following an initial raised clinic reading would reduce misdiagnosis and be cost saving for the NHS, prompting a change in the National Institute for Health and Clinical Excellence (2011) guidelines. This is because additional costs from ambulatory monitoring are counter-balanced by cost savings from better targeting of treatment which accrue over time.

Furthermore, many people currently labelled as hypertensive from clinic blood pressure monitoring alone may not have hypertension. This has significant implications when the adverse effects of labelling per se on otherwise healthy individuals are considered (Haynes et al, 1978; Bloom and Monterossa, 1981; Johnstone et al, 1984; Macdonald et al, 1984).

A caveat

Accuracy in measuring blood pressure is fundamental to the correct diagnosis of hypertension and ambulatory blood pressure measurement is the most accurate non-invasive method of assessing blood pressure. Nevertheless, it remains absolutely essential that the correct procedures in taking blood pressure, as outlined above, are followed. Training is also required to minimize the possibility of poor readings caused by poor technique. Use of an accurate blood pressure monitoring device is also critical to the correct diagnosis of hypertension.

As with clinic blood pressure measurement, an independently validated device should always be used. Validation is the process by which accuracy can be ensured and this involves a comparison of the readings from the device with those from a mercury sphygmomanometer. Critically, any ambulatory machine used should be validated by an appropriate protocol to ensure its accuracy. Monitors can be validated according to one or more of the Association for the Advancement of Medical Instrumentation (1993), International Organization for Standardization (2009), British Hypertension Society (O'Brien et al, 1993a) or European Society of Hypertension International Protocol (O'Brien et al, 2002, 2010) protocols. Lists of current validated monitors are available at the British Hypertension Society (www.bhsoc.org//index.

© 2015 MA Healthcare Ltd

php?cID=247) and dable Educational Trust (www.dableducational.org/sphygmomanometers/devices_3_abpm.html) websites.

A systematic review found published validation studies assessed most ambulatory monitors as accurate but that many such studies failed to adhere to the underlying protocols (Hodgkinson et al, 2013). Furthermore, most monitors which 'passed' validation showed significant variation in blood pressure from the reference standard, highlighting inadequacies in older validation protocols.

Finally, the drift in accuracy of a new device over time is unknown. Monitors should therefore be recalibrated at regular intervals. There are a number of companies who offer this service, although it is important to ensure that they meet ISO9001 standards.

Disadvantages of ambulatory blood pressure measurement

Ambulatory blood pressure measurement may not necessarily be available, outside of larger GP practices and specialist units (Hodgkinson et al, 2011b). Availability has improved following the most recent guidelines (National Institute for Health and Clinical Excellence, 2011), but has depended largely on individual decisions by individual GPs and clinical commissioning groups to pay for the devices on the grounds of their longer-term cost-effectiveness (Lovibond et al, 2011). Anecdotally this has led to patchy availability.

Modern ambulatory monitors are generally lightweight, comfortable and easy to wear, quiet and automated; however, some patients complain that they are disturbed during sleep, which may impact compliance and could also influence detection of the dipper status (Leary and Murphy, 1998). This may be a particular problem for individuals with very high blood pressure, as they are likely to experience frequent repeat readings and a higher cuff pressure. It has nevertheless been suggested that not only can ambulatory blood pressure measurement be easily incorporated into everyday medical practice as a standard diagnostic procedure, as evidenced by more recent large-scale trials, but that, with proper patient instructions and motivation, excellent compliance can be achieved with few complaints of disrupted sleep or diurnal activities (Smolensky et al, 2015). If the patient cannot tolerate ambulatory blood pressure measurement well, home monitoring can be used to confirm the diagnosis.

Does ambulatory blood pressure measurement work in special populations?

Accurate diagnosis is important for correct diagnosis and management but there is evidence that ambulatory blood pressure monitors may be less reliable in some patient groups including elderly patients, patients undergoing haemodialysis, pregnant women and children (Hodgkinson et al, 2013), while oscillometric measurement is difficult in the presence of arrhythmias such as atrial fibrillation. This reflects the difficulty in measuring blood pressure in these populations as much as the performance of the ambulatory monitors, but it is important that clinicians are aware of this difficulty.

Gestational hypertension is a leading cause of direct maternal death in the UK (National Institute for Clinical Excellence et al, 2004). However, in four studies which assessed an ambulatory blood pressure measurement monitor validated in the general population (SpaceLabs 90207) in pregnancy using the British Hypertension Society criteria (O'Brien et al, 1993b; Shennan et al, 1993; Franx et al, 1997; Elvan-Taspinar et al, 2003), two studies found the monitors tested failed to meet the required standard of accuracy (O'Brien et al, 1993b; Franx et al, 1997). The few studies which have examined ambulatory blood pressure measurement in sufficient pre-eclamptic subjects, again assessing the same monitor, found the device failed the British Hypertension Society criteria and performed poorly (Natarajan et al, 1999; Elvan-Taspinar et al, 2003). Similarly, in children the same monitor failed with only 50% of readings within 5 mmHg (Belsha et al, 1996). Although a different ambulatory monitor (A&D TM-2430) has passed validation in children and adolescents (Yip et al, 2012) and a separate monitor (Petr Telegin BPLab) in pregnancy (Bartosh et al, 2006), this nevertheless highlights a need for further research into blood pressure measurement in these special populations.

Conclusions

Ambulatory monitoring provides an accurate assessment of blood pressure over a 24-hour period, is better correlated with prognosis than clinic measurement and can guide both diagnosis and further management.

Several aspects of ambulatory monitoring remain unclear including:

- How to deal with discordant results between home and ambulatory monitoring?
- How often to undertake ambulatory blood pressure measurement?
- Whether additional data from new technology adds value to ambulatory blood pressure measurement, for example, pulse wave analysis or continuous non-invasive ambulatory measurement or cuffless devices?

As ambulatory blood pressure measurement becomes more commonplace in primary as well as secondary care, the answers to these questions should become clearer. **BJHM**

This work forms part of a larger programme considering self-monitoring in primary care and supported by the National Institute for Health Research (NIHR). This programme receives financial support from the NIHR Programme Grants for Applied Research funding scheme and from the NIHR Oxford CLAHRC. The views and opinions expressed are those of the authors and do not necessarily reflect those of the NHS, NIHR or the Department of Health. Professor RJ McManus holds an NIHR Professorship.

Conflict of interest: Professor RJ McManus is funded by an NIHR Professorship and has received funding in terms of blood pressure monitoring equipment for research studies from Omron and Lloyds Pharmacy; Dr JA Hodgkinson, Dr KL Tucker, Professor U Martin, Mrs L Beesley: none.

© 2015 MA Healthcare Ltd

Association for the Advancement of Medical Instrumentation (1993) American national standard. Electronic or automated sphygmomanometer. AAMI, Arlington, VA

Bartosh LF, Dorogova IV, Kuznetsova TN, Krylova AV (2006) Validation of the BPLab 24-hour blood pressure monitor in pregnancy in accordance with the ESH-2001 international protocol. *Arterial Hypertension* **12**(3): 3–6 (in Russian)

Belsha CW, Wells TG, Rice HB, Neaville WA, Berry PL (1996) Accuracy of the SpaceLabs 90207 ambulatory blood pressure monitor in children and adolescents. *Blood Press Monit* **1**: 127–33

Bloom JR, Monterossa S (1981) Hypertension labelling and sense of well-being. *AJPH* **71**(11): 1228–32

Boggia J, Li Y, Thijs L et al; International Database on Ambulatory blood pressure monitoring in relation to Cardiovascular Outcomes (IDACO) investigators (2007) Prognostic accuracy of day vs. night ambulatory blood pressure: a cohort study. *Lancet* **370**: 1219–29

Clark CE, Taylor RS, Shore AC, Campbell JL (2012) The difference in blood pressure readings between arms and survival: primary care cohort study. *BMJ* **344**: e1327 (doi: 10.1136/bmj.e1327)

de la Sierra A, Banegas JR, Segura J et al; CARDIORISC Event Investigators (2012) Ambulatory blood pressure monitoring and development of cardiovascular events in high-risk patients included in the Spanish ABPM registry: the CARDIORISC Event study. *J Hypertens* **30**: 713–19 (doi: 10.1097/HJH.0b013e328350bb40)

Elvan-Taspinar A, Uiterkamp LA, Sikkema JM, Bots ML, Koomans HA, Bruinse HW, Franx A (2003) Validation and use of the Finometer for blood pressure measurement in normal, hypertensive and preeclamptic pregnancy. *J Hypertens* **21**: 2053–60

Fagard RH, Staessen JA, Thijs L (1997) Prediction of cardiac structure and function by repeated clinic and ambulatory blood pressure. *Hypertension* **29**(1 Pt 1): 22–9

Fagard RH, Celis H, Thijs L, Staessen JA, Clement DL, De Buyzere ML, De Bacquer DA (2008a) Daytime and night-time blood pressure as predictors of death and cause-specific cardiovascular events in hypertension. *Hypertension* **51**: 55–61

Fagard RH, Thijs L, Staessen JA, Clement DL, De Buyzere ML, De Bacquer DA (2008b) Prognostic significance of ambulatory blood pressure in hypertensive patients with history of cardiovascular disease. *Blood Press Monit* **13**: 325–32 (doi: 10.1097/MBP.0b013e32831054f5)

Fink JN, Kumar S, Horkan C, Linfante I, Selim MH, Caplan LR, Schlaug G (2002) The stroke patient who woke up: clinical and radiological features, including diffusion and perfusion MRI. *Stroke* **33**(4): 988–93

Franx A, Van Der Post JAM, van Montfrans GA, Bruinse HW (1997) Comparison of an auscultatory versus an oscillometric ambulatory blood pressure monitor in normotensive, hypertensive, and preeclamptic pregnancy. *Hypertens Pregnancy* **16**: 187–202

Haynes RB, Sackett DL, Taylor DW (1978) Increased absenteeism from work after detection and labelling of hypertensive patients. *N Engl J Med* **299**(14): 741–4

Hermida RC, Smolensky MH, Ayala DE et al (2013) 2013 Ambulatory blood pressure monitoring recommendations for the diagnosis of adult hypertension, assessment of cardiovascular and other hypertension-associated risk, and attainment of therapeutic goals. *Chronobiol Int* **30**(3): 355–410 (doi: 10.3109/07420528.2013.750490)

Hodgkinson J, Mant J, Martin U et al (2011a) Relative effectiveness of clinic and home blood pressure monitoring compared to ambulatory blood pressure monitoring in the diagnosis of hypertension: a systematic review. *BMJ* **342**: d3621 (doi: 10.1136/bmj.d3621)

Hodgkinson J, Wood S, Martin U, McManus R (2011b) ABPM is best for diagnosing hypertension in primary care. *Practitioner* **255**(1744): 21–3

Hodgkinson JA, Sheppard JP, Heneghan C, Martin U, Mant J, Roberts N, McManus RJ (2013) Accuracy of ambulatory blood pressure monitors: a systematic review of validation studies. *J Hypertens* **31**(2): 239–50 (doi: 10.1097/HJH.0b013e32835b8d8b)

Imai Y, Ohkubo T, Sakuma M (1996) Predictive power of screening blood pressure, ambulatory blood pressure and blood pressure measured at home for overall and cardiovascular mortality: a prospective observation in a cohort from Ohasama, northern Japan. *Blood Press Monitoring* **1**(3): 251–4

International Organization for Standardization (2009) Non-invasive Sphygmomanometers - Part 2: Clinical validation of automated measurement type. Report No. 81060-2. AAMI, Arlington, VA

Johnstone ME, Gibson ES, Terry CW (1984) Effects of labelling on income work and social function among hypertensive employees. *J Chron Dis* **37**: 417–23

Kain HK, Hinman AT, Sokolow M (1964) Arterial blood pressure measurements with a portable recorder in hypertensive patients, *Circulation* **30**: 882–92

Kario K (2010) Morning surge in blood pressure and cardiovascular risk evidence and perspectives. *Hypertension* **56**(5): 765–73 (doi: 10.1161/HYPERTENSIONAHA.110.157149)

Kario K, White WB (2008) Early morning hypertension: what does it contribute to overall cardiovascular risk assessment? *J Am Soc Hypertens* **2**(6): 397–402 (doi: 10.1016/j.jash.2008.05.004)

Kario K, Pickering TG, Umeda Y et al (2003) Morning surge in blood pressure as a predictor of silent and clinical cerebrovascular disease in elderly hypertensives - A prospective study. *Circulation* **107**(10): 1401–6

Leary AC, Murphy MB (1998) Sleep disturbance during ambulatory blood pressure monitoring of hypertensive patients. *Blood Press Monit* **3**(1): 11–15

Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration (2002) Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet* **360**: 1903–13

Lim SS, Vos T, Flaxman AD et al (2012) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990—2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* **380**(9859): 2224–60 (doi: 10.1016/S0140-6736(12)61766-8)

Lovibond K, Jowett S, Barton P et al (2011) Cost-effectiveness of options for the diagnosis of high blood pressure in primary care: a modelling study. *Lancet* **378**: 1219–30 (doi: 10.1016/S0140-6736(11)61184-7)

Macdonald LA, Sackett DL, Haynes RB (1984) Labelling in hypertension: a review of the behavioural and psychological consequences. *J Chronic Dis* **37**(12): 933–42

Mancia G, Zanchetti A, Agabiti-Rosei E et al (1997) Ambulatory blood pressure is superior to clinic blood pressure in predicting treatment-induced regression of left ventricular hypertrophy. SAMPLE Study Group. Study on Ambulatory Monitoring of Blood Pressure and Lisinopril Evaluation. *Circulation* **95**(6): 1464–70

Mancia G, Fagard R, Narkiewicz K et al (2013) 2013 ESH/ESC Guidelines for the management of arterial hypertension. *J Hypertens* **31**: 1281–357 (doi: 10.1097/01.hjh.0000431740.32696.cc)

Minutolo R, Agarwal R, Borrelli S et al (2011) Prognostic role of ambulatory blood pressure measurement in patients with nondialysis chronic kidney disease. *Arch Intern Med* **171**(12): 1090–8 (doi: 10.1001/archinternmed.2011.230)

Natarajan P, Shennan AH, Penny J, Halligan AW, De Swiet M, Anthony J (1999) Comparison of auscultatory and oscillometric automated blood pressure monitors in the setting of preeclampsia. *Am J Obstet Gynecol* **181**: 1203–10

KEY POINTS

- Ambulatory blood pressure measurement offers certain advantages as a method of monitoring blood pressure: reduced white-coat effect and an ability to assess blood pressure variability, blood pressure dipping at night, and presence of a morning blood pressure surge.
- Ambulatory blood pressure measurement has better correlation with cardiovascular outcomes than clinic blood pressure monitoring.
- Ambulatory blood pressure measurement is the most accurate and cost-effective non-invasive (i.e. not intra-arterial) method of diagnosing hypertension.
- Recent research and guidelines recommend the routine use of ambulatory blood pressure measurement for the diagnosis of hypertension.
- It is important to follow correct procedure and to use an independently validated monitor.

© 2015 MA Healthcare Ltd

National Collaborating Centre for Chronic Conditions (2006) *Hypertension: management in adults in primary care: pharmacological update.* Royal College of Physicians, London

National Institute for Clinical Excellence, Scottish Executive Health Department, Department of Health, Social Services and Public Safety, Northern Ireland (2004) *Why mothers die 2000-2002. The sixth report of the confidential enquiries into maternal deaths in the United Kingdom.* RCOG Press, London

National Institute for Health and Clinical Excellence (2006) *Management of hypertension in adults in primary care.* Clinical Guideline 34. National Institute for Health and Clinical Excellence, London

National Institute for Health and Clinical Excellence (2011) Hypertension: management of hypertension in adults in primary care. Clinical Guideline 127. http://guidance.nice.org.uk/CG127 (accessed 19 October 2015)

O'Brien E, Petrie J, Littler W et al (1993a) British-Hypertension-Society Protocol for the Evaluation of Blood-Pressure Measuring Devices. *J Hypertens* **11**(Suppl 2): S43–S62

O'Brien E, Mee F, Atkins N, Halligan A, O'Malley K (1993b) Accuracy of the SpaceLabs 90207 ambulatory blood pressure measuring system in normotensive pregnant women determined by the British Hypertension Society protocol. *J Hypertens* **11**: S282–S283

O'Brien E, Pickering T, Asmar R et al; Working Group on Blood Pressure Monitoring of the European Society of Hypertension (2002) Working Group on Blood Pressure Monitoring of the European Society of Hypertension International Protocol for validation of blood pressure measuring devices in adults. *Blood Pressure Monit* **7**(1): 3–17

O'Brien E, Atkins N, Stergiou G et al ; Working Group on Blood Pressure Monitoring of the European Society of Hypertension (2010) European Society of Hypertension International Protocol revision 2010 for the validation of blood pressure measuring devices in adults. *Blood Pressure Monit* **15**: 23–38 (doi: 10.1097/MBP.0b013e3283360e98)

O'Brien E, Parati G, Stergiou G et al ; European Society of Hypertension Working Group on Blood Pressure Monitoring (2013) European Society of Hypertension position paper on ambulatory blood pressure monitoring. *J Hypertens* **31**: 1731–68 (doi: 10.1097/HJH.0b013e328363e964)

Ohkubo T, Hozawa A, Nagai K et al (2000) Prediction of stroke by ambulatory blood pressure monitoring versus screening blood pressure measurements in a general population: the Ohasama study. *J Hypertens* **18**(7): 847–54

Palatini P, Reboldi G, Beilin LJ et al (2015) Prognostic Value of Ambulatory Blood Pressure in the Obese: The Ambulatory Blood Pressure-International Study. *J Clin Hypertens* (doi: 10.1111/jch.12700)

Redon J, Campos C, Naciso ML, Rodico JL, Pascual JM, Ruilope LM (1998) Prognostic value of ambulatory blood pressure monitoring in refractory hypertension: a prospective study. *Hypertension* **31**(2): 712–18

Rothwell PM (2010) Limitations of the usual blood-pressure hypothesis and importance of variability, instability, and episodic hypertension. *Lancet* **375**: 938–48 (doi: 10.1016/S0140-6736(10)60309-1)

Shennan AH, Kissane J, De Swiet M (1993) Validation of the SpaceLabs 90207 ambulatory blood pressure monitor for use in pregnancy. *Br J Obstet Gynecol* **100**: 904–8

Shimbo D, Abdalla M, Falzon L et al (2015) Role of ambulatory and home blood pressure monitoring in clinical practice: a narrative review. *Ann Intern Med* (doi: 10.7326/M15-1270)

Smolensky MH, Ayala DE, Hermida RC (2015) Ambulatory Blood Pressure Monitoring (ABPM) as THE reference standard to confirm diagnosis of hypertension in adults: Recommendation of the 2015 U.S. Preventive Services Task Force (USPSTF). *Chronobiol Int* (doi: 10.3109/07420528.2015.1082106)

Staessen JA, Thijs L, Fagard R et al (1999) Predicting cardiovascular risk using conventional vs. ambulatory blood pressure in older patients with systolic hypertension. Systolic Hypertension in Europe Trial Investigators. *JAMA* **282**(6): 539–46

U.S. Department of Health and Human Services (2004) National High Blood Pressure Education Program. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure - Complete Report. www.nhlbi.nih.gov/guidelines/hypertension/jnc7full.htm (accessed 19 October 2015)

Verdecchia P (2000) Prognostic value of ambulatory blood pressure: current evidence and clinical implications. *Hypertension* **35**(3): 844–51

Verdecchia P (2001) Reference values for ambulatory blood pressure and self-measured blood pressure based on prospective outcome data. *Blood Pressure Monit* **6**: 323–7

Verdecchia P, Angeli F, Gattobigio R (2004) Clinical usefulness of ambulatory blood pressure monitoring. *J Am Soc Nephrol* **15** Suppl 1: S30–3

Webb AJ, Fischer U, Mehta Z, Rothwell PM (2010) Effects of antihypertensive-drug class on interindividual variation in blood pressure and risk of stroke: a systematic review and meta-analysis. *Lancet* **375**(9718): 906–15 (doi: 10.1016/S0140-6736(10)60235-8)

White WB (2010) The risk of waking-up impact of the morning surge in blood pressure. *Hypertension* **55**(4): 835–7 (doi: 10.1161/HYPERTENSIONAHA.109.148908)

Whitworth JA, World Health Organization, International Society of Hypertension Writing Group (2003) 2003 World Health Organization (WHO)/International Society of Hypertension (ISH) statement on management of hypertension. *J Hypertens* **21**(11): 1983–92

Williams B, Poulter NR, Brown MJ et al; British Hypertension Society (2004) Guidelines for management of hypertension: report of the fourth working party of the British Hypertension Society, 2004-BHS IV. *J Hum Hypertens* **18**: 139–85

Yip GW, So HK, Li AM, Tomlinson B, Wong SN, Sung RY (2012) Validation of A&D TM-2430 upper-arm blood pressure monitor for ambulatory blood pressure monitoring in children and adolescents, according to the British Hypertension Society protocol. *Blood Press Monit* **17**(2): 76–9 (doi: 10.1097/MBP.0b013e328351d4a4)

CORRESPONDENCE

If you would like to comment on any of the articles in *British Journal of Hospital Medicine,* please write in no more than 250 words to:

Professor Rob Miller, Editor-in-Chief, BJHM
c/o Rebecca Linssen, MA Healthcare, St Jude's Church, Dulwich Road, London SE24 0PB

email: rebecca.linssen@markallengroup.com fax: 020 7978 8316

© 2015 MA Healthcare Ltd