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Hodgkinson, James A.; Tucker, Katherine L.; Martin, Una; Beesley, Louise; McManus, Richard J.

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## **The use of Ambulatory blood pressure measurement (ABPM)**

James A. Hodgkinson<sup>1</sup>, Katherine. L. Tucker<sup>2</sup>, Una Martin<sup>3</sup>, Louise Beesley<sup>4</sup>, and Richard J. McManus<sup>2</sup>

<sup>1</sup> Primary Care Clinical Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT

<sup>2</sup> Department of Primary Care Health Sciences, University of Oxford, OX2 6GG

<sup>3</sup> School of Clinical and Experimental Medicine, University of Birmingham, Edgbaston, Birmingham B15 2TT

<sup>4</sup> Queen Elizabeth Hospital, Queen Elizabeth Medical Centre, Birmingham, B15 2TH

JH is a Research Fellow, KT is a Senior Researcher, UM is a Reader in Clinical Pharmacology and Lead for Hypertension Service, Queen Elizabeth Hospital Birmingham, LB is a Clinical Nurse Specialist in Hypertension, Queen Elizabeth Hospital Birmingham, and RM is a Professor of Primary Care and General Practitioner.

### **Author responsible for correspondence:**

Professor Richard McManus

Tel +44 (0)1865 289300

[richard.mcmanus@phc.ox.ac.uk](mailto:richard.mcmanus@phc.ox.ac.uk)

Department of Primary Health Care Sciences, New Radcliffe House, Woodstock Rd, Oxford, OX2 6GG

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## Short introduction

Measurement of ambulatory blood pressure is recommended by the NICE guidelines to confirm the diagnosis of hypertension in the UK. In this report we describe the use of ambulatory devices and discuss the benefits and disadvantages of its use in clinical practice.

### Key points:

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

## **Main Introduction**

### **Why measure blood pressure?**

Hypertension is a major cause of morbidity and mortality worldwide (Lim et al, 2012) and high blood pressure (BP) is a key risk factor for the development of cardiovascular disease (Prospective Studies Collaboration, 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 ABPM?**

Ambulatory blood pressure measurement (ABPM) is a non-invasive method of obtaining blood pressure readings at regular intervals over twenty-four hours, whilst the patient is in their own environment, undertaking their 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 ABPM 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 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 ABPM 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  $>10\text{mmHg}$  by Clark et al, 2012), when it should be placed on the arm with the highest blood pressure.

Patients taking anti-coagulant therapy or with fragile skin should be assessed for appropriateness, as continual monitoring may lead to localised bruising or compromise skin integrity. The presence of a hemiparesis or any other long standing injury to the arm selected for ABPM, 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 ABPM an unsafe procedure. ABPM may be an uncomfortable experience, however 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 the correct cuff size is used to maximise comfort and accuracy of the readings. Mid arm circumference should be measured and appropriate small, adult, large or extra-large cuff selected. The cable is then threaded across the patient's shoulders and down to the monitor on their opposite hip: this can be attached to a belt or harness.

Patients should be instructed to undertake their normal activities, with consideration to 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 whilst 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 (overleaf).

It is important to consider practical issues relating to ABPM. 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 whilst on a patient.

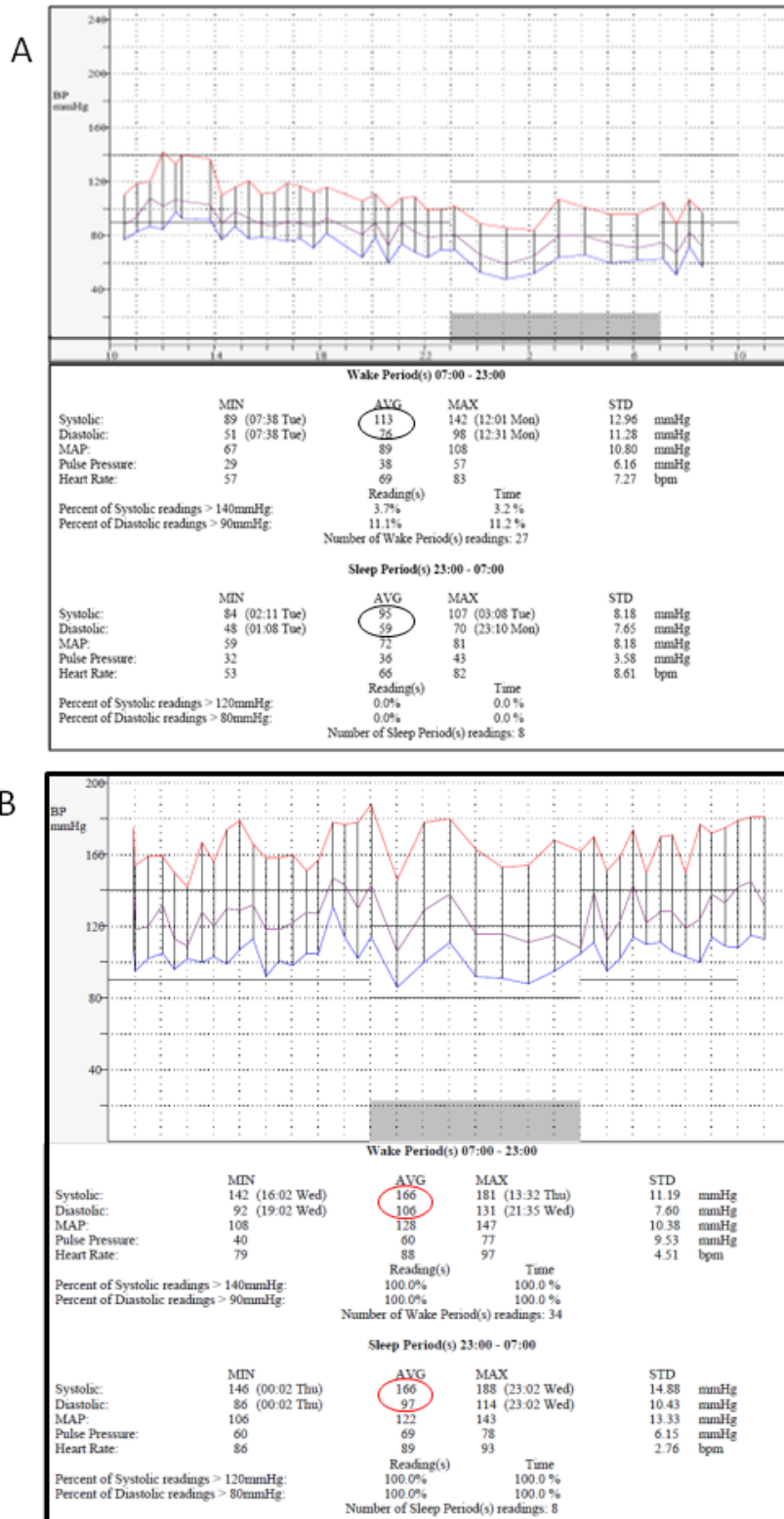
### **Interpretation of ABPM**

In order to compare to clinic BP readings, mean daytime systolic BP has to be adjusted upward by 5-10mmHg and mean daytime diastolic BP has to be adjusted upward by 5mmHg, but this assumed difference can vary considerably and is usually greater in people with a higher baseline BP and as people age [see below for influence on diagnostic thresholds]. Maintaining a diary of events during ABPM 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 BP can then be used, calculated according to the record kept by each patient.



**Figure 1: Examples of a 24 hour measurement of ambulatory blood pressure, recorded using an ABPM monitor.**

Readings from a normotensive individual with the average systolic and diastolic readings circled in black (A) and readings from a hypertensive individual with the average systolic and diastolic readings circled in red (B).



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

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

### **What can ABPM 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 Organisation, International Society of Hypertension Writing Group, 2003). It has therefore arguably become the de facto reference standard for the diagnosis of hypertension (Hodgkinson et al, 2011a).

ABPM, 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 due to the stress of being in a medical situation (Verdecchia et al, 2004).

A major advantage of ABPM is that it provides more information than either home or clinic BP measurements because more readings are taken. Clinical BP measurements in particular are fewer in number, and so more subject to general

variability including regression to the mean. 24-hour ABPM allows estimates of increased cardiac risk including excessive BP variability or failure to reduce BP nocturnally. Blood pressure variability is recognised as a key element in subsequent risk of cardiovascular disease and stroke in particular (Rothwell, 2010). However, whilst 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 ABPM can determine night-time dipping patterns, which have important prognostic implications. ABPM allows BP to be intermittently monitored during sleep, and is useful to determine whether the patient is a dipper or non-dipper, i.e. whether or not BP 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 (MBPS) is thought to be a risk factor for wake up stroke (which is implicated in up to 27% of all ischemic strokes [Fink et al, 2002]) and indeed other cardiovascular events that occur in the morning hours (Kario and White, 2008; Kario, 2010; White, 2010). MBPS is commonly assessed by ABPM and defined as the sleep-trough surge, calculated by subtracting the morning BP (mean of four readings over two hours just after wake-up) from the lowest nocturnal BP (mean of three readings centred around the lowest night time BP) (Kario et al, 2003; Kario, 2010). However, there are several alternative definitions but only ABPM 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 ischemic episodes.

### **Why is ABPM particularly important now?**

Initial management of hypertension has conventionally required a diagnosis based on several elevated clinic or office blood pressure measurements (Williams et al, 2004; JNC 7, 2004; National Institute for Clinical Excellence, 2006; National Collaborating Centre for Chronic Conditions, 2006). Even in the infancy of ABPM, early evidence found ambulatory BP correlated with target organ damage. Now it is acknowledged that ABPM 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).

The benefits of out-of-office techniques, in particular ABPM, include the correct diagnosis of white coat hypertension, and improved diagnostic accuracy. Indeed, the weight of evidence suggests ABPM is the best prognostic indicator, followed by home BP monitoring, and then clinic BP monitoring. Thus ABPM is best able to predict those patients who require treatment. Its greater use should result in both improved outcomes for patients and lower costs to the NHS through both reduced anti-hypertensive 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 recent systematic review (Hodgkinson et al, 2011a) and cost-effectiveness study (Lovibond et al, 2011) found ABPM 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 latest NICE guidelines (National Institute for Clinical Excellence, 2011). 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 BP 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; Macdonald et al, 1984; Johnstone et al, 1984).

### **A caveat**

Accuracy in measuring BP is fundamental to the correct diagnosis of hypertension and ABPM has been shown to be the most accurate non-invasive method of assessing BP. Nevertheless, it remains absolutely essential that the correct procedures in taking BP, as outlined above, are followed. Training is also required to minimise 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 AAMI/ ISO (Association for the Advancement of Medical Instrumentation, 1993; International Organization for Standardization, 2009), BHS (O'Brien et al, 1993a) or ESH-IP (O'Brien et al, 2002; O'Brien et al, 2010) protocols. Lists of current validated monitors are available at the BHS (British Hypertension Society, 2013) and DABL (O'Brien et al, 2013) websites.

A recent 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, though it is important to ensure that they meet ISO9001 standards.

### **Disadvantages of ABPM**

ABPM is not widely available, with only around one in every twenty diagnoses made with an ABPM machine, and to date these have been largely confined to larger GP practices and specialist units (Hodgkinson et al, 2011b). This is likely to change following the recent update to NICE guidelines (National Institute for Clinical Excellence, 2011), but as the guidelines are not mandatory, questions remain over whether GPs will be convinced enough of the benefits to pay for the devices despite their longer-term cost-effectiveness (Lovibond et al, 2011).

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. Home monitoring can be used to confirm the diagnosis if the patient cannot tolerate ABPM well.

### **Does ABPM 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, haemodialysis patients, pregnant women, and children (Hodgkinson et al, 2013), whilst 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 ABPM monitor validated in the general population (SpaceLabs 90207) in pregnancy using the BHS 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 ABPM in sufficient pre-eclamptic subjects, again assessing the same monitor, found the device failed the BHS 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 5mmHg (Belsha et al, 1996). This 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 ABPM?
- Whether additional data from new technology adds value to ABPM, for example, pulse wave analysis or continuous non invasive ambulatory measurement or cuffless devices?



As ABPM becomes more common place in primary as well as secondary care, these questions should become clearer.

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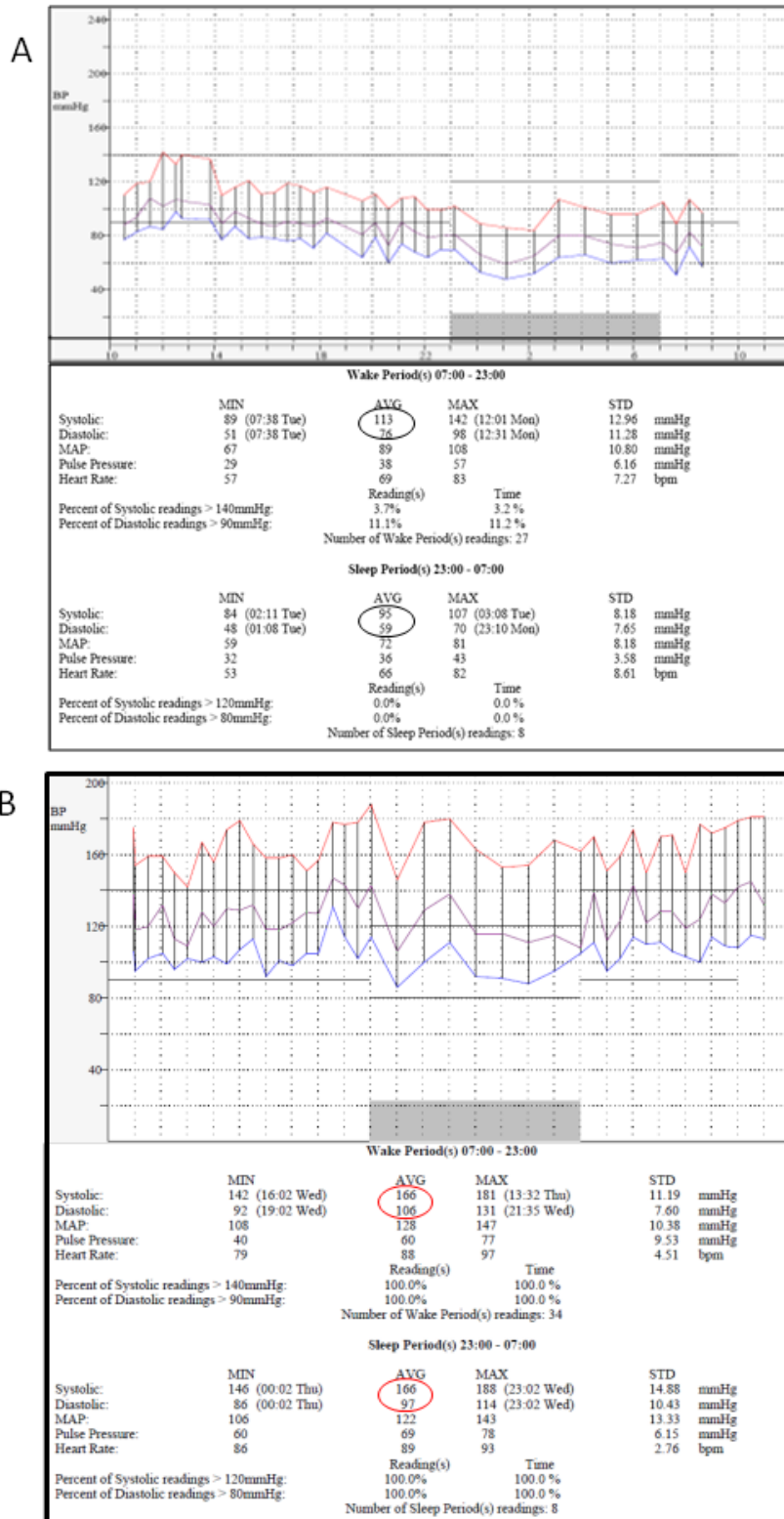
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