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Ambulatory blood pressure monitoring

Rationale for non-invasive ambulatory blood pressure monitoring (ABPM)

"Blood pressure is a quantity with a very large range...hypertension is a quantitative disease." Sir George Pickering (1954)

The management of hypertension during the past 50 years has been based on casual blood pressure readings in the doctor's office or clinic. However the inherent variability of blood pressure and the limitations of clinic measurements have been recognised for many years. A single measurement of blood pressure by use of an occluding cuff and listening to the Korotkoff sounds provides a reasonable estimate of the prevailing blood pressure, but it is only a minute sample of the 100,000 or so heart beats per day.

Moreover, the random variability in blood pressure throughout the day is such that the mean difference between the highest and lowest blood pressure recordings during the waking hours of a normal day in a group of normal subjects has been estimated at 35/23 mmHg. There is a pronounced diurnal change in blood pressure, with a significant fall during sleep. Although the variations tend to be smaller during night time sleep than during the day, blood pressure may rise sharply with an external stimulus or change spontaneously with changes in the EEG pattern.

Another reason casual BP measurements may be unreliable relates to the so-called "white-coat" effect. It has been demonstrated in a number of studies that 15-25% of subjects with repeatedly elevated clinic blood pressure readings have normal blood pressure profiles on ABPM. These subjects (defined as having "white coat" hypertension) are more likely to be younger, female, and to weigh less than patients whose pressures are elevated both in the clinic and on ambulatory monitoring. The phenomenon is more pronounced when blood pressure is measured by a doctor than a nurse or technician, hence the "white coat" tag. It has been observed to persist in patients followed up for many years, and does not clearly relate to anxiety, but may represent a conditioned response. Those patients who state that their blood pressure rises every time they see a sphygmomanometer cuff may well be correct.

Little wonder, therefore, that single measurements fail to accurately reflect the average level of blood pressure. How many readings, and over what period of time, should

recordings be made, to give a good estimate of average daily blood pressure? It has been suggested that periods as short as 2-3 hours may be enough, but direct recordings have shown this to be inadequate, and it is recommended that recordings need to be made over 8-12 hours at half-hour intervals.

Apart from theoretical and statistical reasons for thinking that multiple ambulatory blood pressure recordings are preferable to single clinic recordings, there is increasing evidence that average blood pressure from ambulatory recordings may be a better prediction of cardiovascular morbidity in hypertensive subjects.

At least eight studies have shown better correlation between left ventricular mass or wall thickness determinations and average ABPM readings compared to casual blood pressures. Perloff and colleagues have followed hypertensive subjects prospectively over 20 years and found that higher mean awake ABP's predict cardiovascular events over and above age, office BP's, and evidence of target organ damage.

The risks of hypertension, and the benefits to be derived from pharmaceutical treatment, have been well defined in epidemiological studies and the large multicentre therapeutic trials. The Australian National Blood Pressure Study showed that patients with diastolic blood pressures between 90 and 104 mmHg benefited from active treatment. However, in that study of mild uncomplicated hypertension 30% of subjects achieved a diastolic blood pressure of <90 mmHg on placebo treatment. Similar results have been reported from the American High Blood Pressure Detection and Follow-up Program and the British MRC trial. The tendency for blood pressure to decrease over time, regardless of the type of treatment, has been one of the more striking findings to emerge from the large scale clinical trials of the treatment of mild hypertension. Thus the doctor faced with mild uncomplicated hypertension based on casual readings obtained over a short period of time has a dilemma - when and on what grounds should drug treatment be initiated if the baseline is shifting? In contrast to casual readings, ABPM profiles tend to be reproducible with time, so that only one period of ABP monitoring is required for an accurate assessment of blood pressure. However, to date there have been no randomised controlled trials of antihypertensive treatment using ABPM classification of hypertension and with cardiovascular morbidity or mortality as end-points.

Critics of ABP classification of hypertension suggest that patients who show high blood pressure readings in the clinic situation are likely to have exaggerated blood pressure responses to daily stresses and therefore should be treated, even if it is suspected that they may be clinic hyper-responders or "white coat" hypertensives. This is because the damaging effects of blood pressure relate not only to the average levels of blood pressure but also to the peaks that are usually associated with increased sympathetic activity. Recent studies by Pickering and colleagues do not support this view.

It remains to be determined if subjects with so-called "white coat" hypertension face any greater risk of cardiovascular morbidity than age-and sex-matched normal subjects. At this time it is important to try to identify such subjects and to follow them

without necessarily resorting to drug therapy. ABPM is the only way to identify such subjects and the results can be helpful in providing reassurance.

An argument to extend availability and use of ABPM beyond clinical research is based on the savings of drug costs in newly diagnosed hypertensive patients who would otherwise receive drug therapy. The cost of drug therapy for the treatment of hypertension in the Australian community is more than \$250m per annum and increasing rapidly. This represents some \$100 per patient per year. This is a recurrent cost for the life of the patient and techniques which can identify patients who do not require drug treatment could save the community a considerable sum. There is potential for considerable cost savings to be made by more accurately classifying hypertensive subjects and identifying those "clinic responders" or "white coat hypertensives" in whom drug therapy can be avoided. As discussed previously, up to 25% of newly diagnosed mild "hypertensive" subjects fall into this category. When ABPM is employed in patients with hypertension other cost savings may result from more appropriate tailoring of antihypertensive therapy. A change in patient compliance with therapy is a potential advantage but this has not yet been formally evaluated.

Suggested indications for use of ABPM

The following are suggested indications for ABPM in subjects with established or suspected hypertension in the Australian community. These recommendations have been proposed by a working party of the High Blood Pressure Research Council of Australia.

1. Patients with newly discovered 'hypertension' whose casual office or clinic blood pressure levels are in the mild category (DBP<100mmHg) with no evidence of target organ (end organ) damage.
2. Patients with borderline or labile hypertension.
3. Blood pressure management in the patient whose blood pressure is apparently poorly controlled despite the use of appropriate antihypertensive drug therapy.
4. Patients who exhibit worsening of end-organ damage despite adequate blood pressure control on office or clinic readings.
5. To convincingly demonstrate inadequate blood pressure control to appropriate patients in an effort to enhance understanding of their blood pressure problem and treatment compliance.
6. A history suggestive of syncope or orthostatic hypotension. In such patients ABPM may be best used in conjunction with Holter monitoring.
7. Symptoms or signs suggestive of episodic hypertension as in pheochromocytoma.
8. Clinical research: Because data from ABPM contains many more samples of blood pressure readings, data from this source is much more statistically robust than isolated measurements. Demonstrations of significant effects of treatment

is possible with smaller numbers of patients. This is very important for the efficient evaluation of new therapeutic agents.

Technical aspects of non-invasive ABPM

Available instruments use a variety of techniques of blood pressure measurements according to one or more of the following principles:

- i. Auscultation with detection of onset and disappearance of Korotkoff sounds by a microphone placed over an artery distal to a deflating compression cuff.
- ii. Cuff oscillometry which relies on detection of cuff pressure oscillations. Systolic and diastolic pressures correspond to cuff pressures at which oscillations first increase (systolic BP) and cease to decrease (diastolic BP). The end-points are approximated by an analysis of oscillation amplitudes and cuff pressures.
- iii. Volume oscillometry, usually of a finger, with detection of volume pulsations under an occluding cuff. Systolic and mean pressures are estimated as the cuff pressures at which finger volume oscillations commence and become maximal respectively. Diastolic pressure is derived.

These three principles rely on different vascular phenomena during arterial compression. Auscultatory methods depend on a flow phenomenon and tend to underestimate systolic pressure. Oscillometric methods may overestimate systolic pressure because of transmitted cuff pressure oscillations even at cuff pressures above true systolic pressures. Finger pressures have a variable relationship to brachial blood pressure and there are inherent problems in assessing diastolic blood pressure by finger oscillometry. There have been rapid technological developments in ambulatory blood pressure monitoring devices.

The first machine, developed by Inman in 1962, used a microphone taped over the brachial artery, an occlusive cuff inflated by the subject, and a magnetic tape recorder for recording cuff pressures, ECG and K-sounds. It weighed 2.5 kg. A modified version was used by Sokolow and colleagues in 1966 in a classic study relating average blood pressures to end-organ damage. The first fully automated instrument was developed by Schneider and colleagues using compressed Carbon di-oxide to inflate the cuff. An electric pump was used for the first time in the Pressureometer II (Del-Mar-Avionics) and automatic data retrieval systems have been available since 1979.

The past 6 years has seen the emergence of a number of fully automated, microprocessor controlled instruments which have become progressively lighter (<500g), quieter and more sophisticated with programmable and computer interactive facilities.

Readings obtained from modern ABP monitors (eg Accutracker II, Spacelabs) generally agree closely with sphygmomanometer readings. In a recent study from our department, over a wide range of pressures, the mean \pm S.D. of differences between blood pressures measured by the Accutracker II and mercury sphygmomanometer were $0.5 \pm 7/-0.5 \pm 6$ mmHg (n=79 subjects, 237 paired observations). Documentation of accuracy and reliability of equipment has been generally slow to emerge. Standards protocol for assessment have been developed by the British Society of Hypertension and the Association for the Advancement of Medical Instrumentation (USA, 1986). There may be technical reasons why ambulatory readings fail in some patients, eg. weak or irregular pulse, auscultatory gap or other physical characteristics. Although movement and physical activity may result in invalid readings with most equipment, modern models compensate for this by taking a repeat measurement if movement artifact is suspected.

Analysis of ABPM

Each profile of ABPM produces a large number of readings. Modern machines are programmed to take additional readings if apparent errors occur. Our unit's experience over the past 5 years is that an average of 60 readings are obtained from each 24 hour ABPM profile when the Accutracker II device is programmed to take half-hourly recordings during the daytime and hourly at night. This includes calibration, patient-initiated recordings and retries. It is strongly recommended that all subjects should maintain a diary, and records should include times of medication and sleep. Data handling is best done using a computer (PC) and reports should include relevant information from the subject's diary. It is now recommended that data editing should be kept to a minimum with exclusion only of failed readings (usually show zero) and major technical errors identified as machine generated codes. The following are useful analyses: mean daytime and sleep/night time ambulatory blood pressure; work-time ambulatory blood pressure; percentage of blood pressures $> 140/90$ while awake and $> 120/80$ during sleeping hours or the integrated area under the blood pressure curve above the same values ('blood pressure load').

There is emerging epidemiological data on what are 'normal' values. In one population study by Staessen et al (1991) median daytime values (95th centile) were as follows:

men 20-49 yrs 126/77 (144/95); „ 50 yrs 124/78 (154/90);

women 20-49 yrs 118/73 (132/85); „ 50 yrs 122/74 (151/95)

Median night-time values (95th centile) were:

men 20-49 yrs 110/62 (124/79); „ 50 yrs 107/62 (140/83);

women 20-49 yrs 104/58 (121/70); „ 50 yrs 106/62 (132/72)

In an Australian population study, we studied a randomly selected sub-group of the NHF Risk Factor Prevalence Study 1989 attending Melbourne screening centres. Accutracker II devices were worn by 79 of the 848 participants. Untreated hypertension was identified in 20 subjects by the survey mercury sphygmomanometer technique (mean „ 150/90), six of whom had a mean daytime ambulatory blood pressure < 135/85 suggesting 'normotension' on ambulatory criteria. Conversely 19 subjects had a mean daytime ambulatory blood pressure of „ 135/85, five of whom had 'normal' survey blood pressures. Thus 'survey' and ambulatory blood pressure measurements for defining hypertension show significant discordance. This highlights the need for prospective studies in which both forms of measurement are employed.

When is ABPM inappropriate?

In patients with clearly elevated blood pressure readings, evidence of end-organ damage and other cardiovascular risk factors ABPM is not required for diagnostic purposes. Also, given the remarkable reproducibility of ABPM profiles, repeated measurements have no advantages in patients once established on a satisfactory antihypertensive regimen with good evidence of control.

Staff training, calibration of devices and adherence to a set of quality control guidelines are essential. Data analysis and interpretation require considerable care and it is for this reason that we would discourage the use of reports that arise solely from automatic data recovery units.

Self-measurements of blood pressure versus ABPM

Self-measurement of blood pressure, i.e. readings taken by lay persons on themselves or on a family member, is of clinical value in several ways. In selected patients it may be useful in confirming the diagnosis of hypertension, assessing the effects of therapy, documenting blood pressure patterns, improving patient compliance, and encouraging patients and their families to participate more actively in treatment programs. Some problems with self-measurement include the need for training, problems with technique and equipment, inaccurate readings and misunderstanding of observed values. Self-measurement may not suit some patients who become alarmed or concerned, as well as those who misinterpret or overreact to one or more measurements. Self-measurement may be influenced by social, cultural, medical and economic factors. As well as mercury and aneroid manometers, there is a wide range of electronic devices,

the accuracy and reliability of which need to be carefully checked and all instruments should be regularly calibrated.

Non-invasive ABPM has advantages compared to self-monitoring. It can provide many more readings on any one day, with less inconvenience and it gives highly reproducible profiles of blood pressure. More importantly, ambulatory blood pressure monitoring does not require patient training and can be used in virtually all patients. However, the available equipment is much more expensive than even the most complex electronic home-measurement device and requires trained staff for fitting monitors, data analysis and interpretation of blood pressure profiles.

The future of ABPM

Currently there are only a few Australian centres offering this service. It is expected that many more centres will become involved in the near future even though the equipment is expensive and there is at present no item number for the procedure. More data is needed to define normal ranges of ABPM levels, and especially their prognostic significance. The emergence of many new machines highlights the need for careful evaluation of equipment to ensure accuracy and reliability.

There is little doubt as to the value of the procedure in the assessment of blood pressure disorders. The results obtained are challenging our view on the nature and very definition of hypertension and providing important data on different patterns of blood pressure responses to daily activities. It is a quiet revolution providing us with a new perspective on the pressure to treat.

Address for correspondence:

Associate Professor BP McGrath
Department of Medicine
Monash Medical Centre
247 Clayton Road, Clayton
MELBOURNE VIC 3168
Fax (03) 9550-5524

Recommended further reading

1. Hypertension Detection and Follow-up Program Co-operative Group. Five-year findings of the hypertension detection and follow-up program: 1. Reduction in mortality of persons with high blood pressure, including mild hypertension.

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This report was prepared for the National Heart Foundation's Blood Pressure Advisory Committee by Barry McGrath MB BS MD FRACP.



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