4 Measurement of blood pressure

Eoin O'Brien

Part I Aspects of measurement of blood pressure common to technique and patient

Technique

Selection of an accurate device
An accurate device is fundamental to all measurements of blood pressure. If the device is inaccurate, attention to the detail of measurement methods is of little relevance. The accuracy of devices for measurement of blood pressure should not be judged on the sole basis of claims from manufacturers, which can be extravagant. Instead devices should be validated according to international protocols in peer reviewed journals.

The website dableducational provides updated assessments of all devices used to measure blood pressure and indicates which have passed or failed independent validation (see example table below—for full details go to www.dableducational.org)

Sphygmomanometers for self-measurement of blood pressure—devices for the upper arm

Device	Mode of measurement	AAMI	BSH	ESH	Circumstance	Recommendation
A&D UA-631 (UA-779 Life Source)	Oscillometric			Pass	At rest, recruitment violations	Recommended
A&D UA-704	Oscillometric		A/A		Study details omitted	Questionable
A&D UA-767	Oscillometric	Pass	A/A		At rest; not high blood pressure	Recommended
A&D UA-767 Plus	Oscillometric		A/A A/A A/A		At rest; tables incomplete At rest; recruitment violations At rest; recruitment violations; simultaneous readings	Recommended Questionable Questionable
A&D UA-787	Oscillometric			Pass		Recommended
Microlife BP 3AC1-1	Oscillometric			Pass		Recommended
Microlife BP 3BTO-A	Oscillometric	 Pass Pass Pass	A/A A/B B/B A/B		Small recruitment violation Normotensive pregnancy Non-proteinuric high blood pressure Pre-eclampsia	Recommended Recommended
Omron HEM-705IT	Oscillometric			Pass		Recommended
Omron M5-I	Oscillometric			Pass		Recommended
Omron MX3 Plus	Oscillometric			Pass	Recruitment ranges omitted; from plot, high range of diastolic blood pressure seems undersubscribed	Questionable
Rossmax	Oscillometric on inflation			Fail	At rest	Not recommended
Visomat OZ2	Oscillometric	Pass	C/B		At rest	Not recommended
Welch-Allyn transtelephonic home monitor	Oscillometric	Pass			Parkinson's disease	Questionable

AAMI = American Association of Medical Instrumentation; BHS = British Hypertension Society; ESH = European Society for Hypertension.

Variability of blood pressure
No matter which measurement device is used, blood pressure is always a variable haemodynamic phenomenon. Modification of the factors that influence variability is not always possible, but we can minimise their effect. When optimum conditions are not possible, this should be noted with the reading.

White coat hypertension and the white coat effect
Anxiety increases blood pressure—often by as much as 30 mm Hg—when patients are frightened and extremely anxious, when it is often referred to as the white coat effect. This effect should be distinguished from white coat hypertension, in which a person with normal blood pressure has hypertension during measurement by doctors and nurses but blood pressure returns to normal away from the medical environment. White coat

Factors that influence blood pressure variability

- Circumstances of measurement
- Respiration
- Emotion
- Exercise
- Meals
- Tobacco
- Alcohol
- Temperature
- Bladder distension
- Pain
- Age
- Race
- Diurnal variation (blood pressure lowest during sleep)

hypertension is shown best by ambulatory blood pressure measurement (Part III).
These white coat phenomena are important because a decision to reduce blood pressure, and especially to administer drugs, never should be made on the basis of measurements taken in circumstances in which the white coat effect or white coat hypertension is likely to occur.

Optimum conditions for measurement

- Relaxed patient
- Comfortable temperature
- Quiet room—no telephones or noises

Posture

Posture affects blood pressure, with a general tendency for it to decrease when a person moves from the lying position to the sitting or standing positions. Some patients may have postural hypotension, especially those who are taking certain antihypertensive drugs and elderly people. When this is likely, blood pressure should also be measured when the patient is standing.

Arm support

If the arm in which blood pressure is being measured is unsupported—as tends to happen when the patient is sitting or standing—the patient is performing isometric exercise, which increases blood pressure by as much as 10%. The arm therefore must be supported during measurement of blood pressure, especially when the patient is in the standing position. This is achieved best in practice by the observer holding the patient's arm at the elbow.

Arm position

The forearm should be at the level of the heart—that is, the mid-sternum. Measurement in an arm lower than the level of the heart leads to an overestimation of systolic and diastolic pressures, while measurement in an arm above the level of the heart leads to underestimation. Such inaccuracy can be as much as 10 mm Hg, especially when the patient is in the sitting or standing position, when the arm is likely to be below heart level by the side. Arm position is important for self measurement of blood pressure with devices for wrist measurement. Many of these devices inherently are inaccurate, but measurement is even less accurate if the wrist is not held at the level of the heart during measurement.

Which arm?

Arterial disease can cause differences in blood pressure between arms, but because blood pressure varies from beat to beat, any differences may simply reflect blood pressure variability or measurement errors, or both. Bilateral measurement should be made at the first consultation; if differences >20 mm Hg for systolic or 10 mm Hg for diastolic blood pressure are present on consecutive readings, the patient should be referred to a cardiovascular centre for further evaluation with simultaneous bilateral measurement and the exclusion of arterial disease.

Cuff and bladder

The cuff is an inelastic cloth that encircles the arm and encloses an inflatable rubber bladder. The cuff is secured around the arm most often by means of Velcro on the adjoining surfaces of the cuff, occasionally by wrapping a tapering end into the encircling cuff, and rarely by hooks. Velcro surfaces must be effective; when they lose their grip, the

White coat phenomena

White coat effect

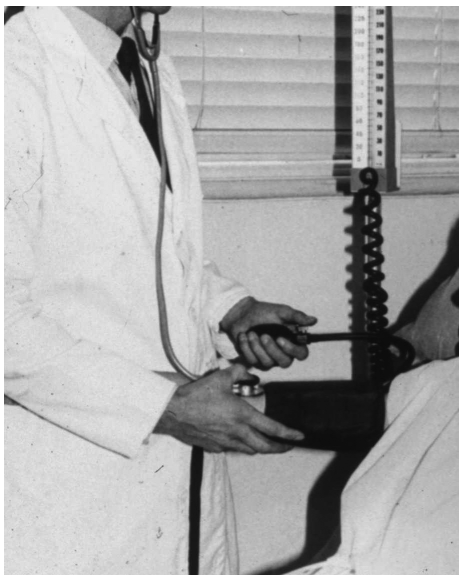
- Also know as: Fight and flight phenomenon, alarm reaction, defence reaction
- Occurs in medical environment—for example, emergency department or surgery
- Occurs in people with normal blood pressure and hypertension
- Decreases with familiarisation

White coat hypertension

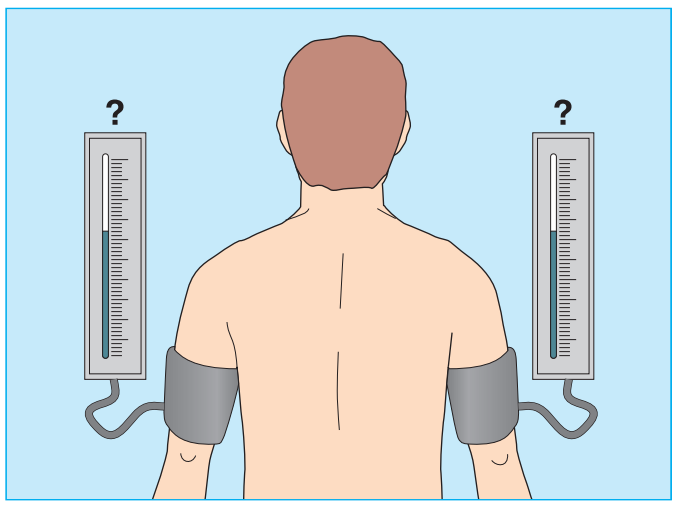
- Occurs in medical environment
- People with normal blood pressure become hypertensive. People with hypertension have higher blood pressures in a medical environment
- Tends to persist during repeated visits

Posture and position

- Measure blood pressure routinely with patient in sitting position
- Back should be supported
- Legs should be uncrossed
- Patient should be relaxed
- Measure after ten minutes of rest
- Measure after two minutes of standing if indicated



Arm support during blood pressure measurement



Which arm?

cuff should be discarded. The bladder should be removable from the cuff for washing.

Cuff hypertension

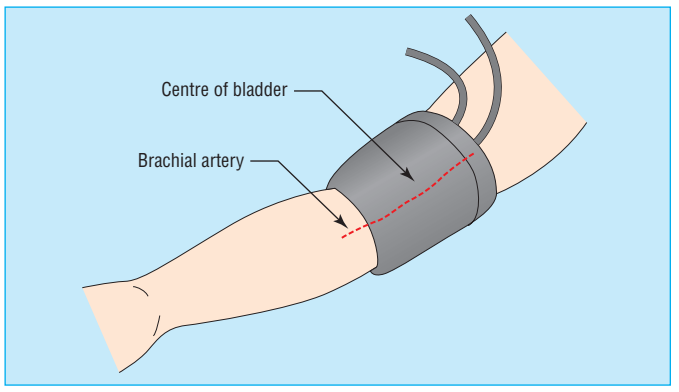
However sophisticated a blood pressure measuring device, if it is dependent on cuff occlusion of the arm (as most devices are), it will be prone to the inaccuracy of miscuffing. This occurs when a cuff contains a bladder that is too long or too short relative to the circumference of the patient's arm. Miscuffing is a serious source of error that leads inevitably to incorrect diagnosis in clinical practice and erroneous conclusions in research into hypertension. A further problem is that inflation of the cuff itself may result in a transient but substantial increase (up to 40 mm Hg) in the patient's blood pressure.

Solutions

Correction factors on the cuff to avoid measurement errors from an inappropriate bladder complicate blood pressure measurement and are not used often. Cuffs that contain a variety of bladders of varying dimensions are available (such as Tricuff, Pressure Group AB, Sweden), but they are expensive and can be difficult to apply because of stiffness of the cuff. A "universal" cuff adjustable for all arm dimensions has been proposed but not manufactured successfully yet.

A cuff that contains a bladder that measures 35 × 12 cm was used for a time on the basis that it would encircle most adult arms, but it introduced errors by overcuffing lean arms. Many national bodies now recommend a range of cuffs to cater for all eventualities, which presupposes that the user will measure the arm circumference and, having done so, will have access to an adequate range of cuffs. In practice, neither of these requirements is easily fulfilled.

Unfortunately, societies differ in their recommendations. The striking difference between the American and British recommendations is not so much the length of the bladders but the width: most European arms will comfortably accommodate a bladder with a width of 12 cm, but a bladder with a width of 16 cm is likely to encroach on the antecubital fossa—particularly if (as often happens in practice) the sleeve of the patient's shirt or blouse is rolled up.



Placement of cuff

Mismatching of bladder and arm

Bladder too small (undercuffing)	Bladder too large (overcuffing)
• Overestimation of blood pressure	• Underestimation of blood pressure
• Range of error: —3/3 to 12/8 mm Hg —As much as 30 mm Hg in patients who are obese	• Range of error: —10–30 mm Hg

Undercuffing is more common than overcuffing

Cuffing solutions

- Correction factors on the cuff
- Cuffs containing a variety of bladders of varying dimensions
- A universal cuff for all arms
- A cuff suitable for most arms

Recommended bladder dimensions for adults

British Hypertension Society

Cuff type	For whom	Dimensions (cm)
Small	Lean adult arms and children	12 × 18
Standard	Most adult arms	12 × 26
Large	Arms of obese patients	12 × 40

American Heart Association

Cuff type	Arm circumference (cm)	Dimensions (cm)
Small adult	22 – 26	12 × 22
Adult	27 – 34	16 × 30
Large adult	35 – 44	16 × 36
Adult thigh	45 – 52	20 × 42

The subject

Special management of blood pressure

Certain groups of people merit special consideration for the measurement of blood pressure—because of age, body habitus, or disturbances of blood pressure related to haemodynamic alterations in the cardiovascular system.

Children

Measurement of blood pressure in children presents a number of difficulties. Variability of blood pressure is greater than in adults, and any one reading is less likely to represent the true blood pressure. Systolic pressure is more accurate and reproducible than diastolic pressure. A cuff with proper dimensions is essential for accurate measurement. The widest cuff practicable should be used.

Ideally, blood pressure should be measured after a few minutes of rest. Values obtained during sucking, crying, or eating will not be representative. As with adults, a child's blood pressure status should be decided only after it has been measured on a number of separate occasions.

Recommended bladder dimensions for children aged 0–14 years

Cuff type	Dimensions (cm)
1	4 × 13
2	8 × 18
3	12 × 26

Korotkoff sounds are not audible reliably in any child younger than one year and in many children younger than five years, so Doppler ultrasound or oscillometry should be used

Body size is the most important determinant of blood pressure in childhood and adolescence. The US National High Blood Pressure Education Group on Hypertension Control in Children and Adolescents provides blood pressure ranges that relate to age and height.

Blood pressure can vary considerably in elderly people (photos.com)

Elderly people

In epidemiological and interventional studies, blood pressure predicts morbidity and mortality in elderly people as effectively as in the young. Elderly people have considerable variability in blood pressure, which can lead to a number of diurnal blood pressure patterns that are identified best with measurement of ambulatory blood pressure (see Part III).

Isolated systolic hypertension—This is the most common form of hypertension in elderly people.

Hypotension—Blood pressure in elderly people can vary greatly in those with autonomic failure, with periods of hypotension interspersed with hypertension on measurement of ambulatory blood pressure. As elderly people especially can be susceptible to the adverse effects of antihypertensive drugs, identification of postural hypotension particularly becomes important. Some elderly patients experience quite a marked decrease in blood pressure after eating, and this may be symptomatic. This again is diagnosed best by measurement of blood pressure when a patient is standing after a meal or with ambulatory blood pressure.

White coat hypertension—Elderly people are affected by the white coat phenomenon even more than young people.

Pseudohypertension—This term describes a large discrepancy between cuff and direct measurement of blood pressure in elderly patients. When conventional measurements seem to be out of proportion with the clinical findings, referral to a specialist cardiovascular centre for further investigation may be an appropriate option.

Causes of hypotension in elderly patients

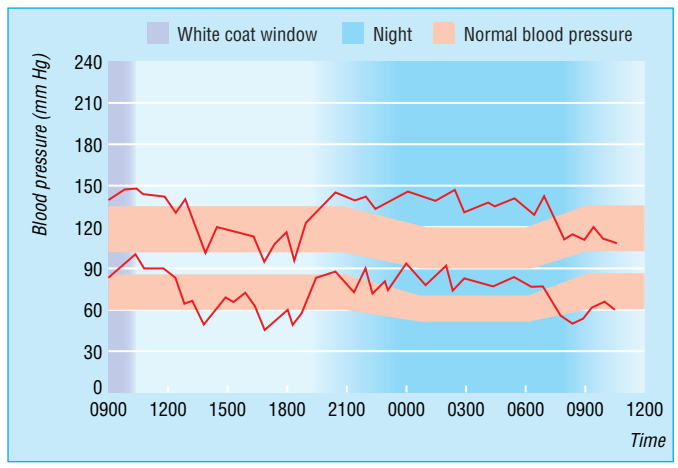
- Standing—postural hypotension
- Autonomic failure
- Drugs
- Meals—post-prandial hypotension
- Diabetes mellitus
- Parkinson's disease

Obese people

The association between obesity and hypertension has been confirmed in many epidemiological studies. Obesity may affect the accuracy of measurement of blood pressure in children, young and elderly people, and pregnant women. The relation of arm circumference to bladder dimensions is particularly important. If the bladder is too short, blood pressure will be overestimated—"cuff hypertension"—and if it is too long, blood pressure may be underestimated. The increasing prevalence of the metabolic syndrome, of which hypertension is a major component, means that accurate measurement of blood pressure increasingly becomes important.

Arrhythmias

Large variations in blood pressure from beat to beat make it difficult to obtain accurate measurements in patients with arrhythmias. In patients with arrhythmias such as atrial fibrillation, blood pressure varies depending on the preceding pulse interval. No generally accepted method of determining auscultatory endpoints in patients with arrhythmias exists.



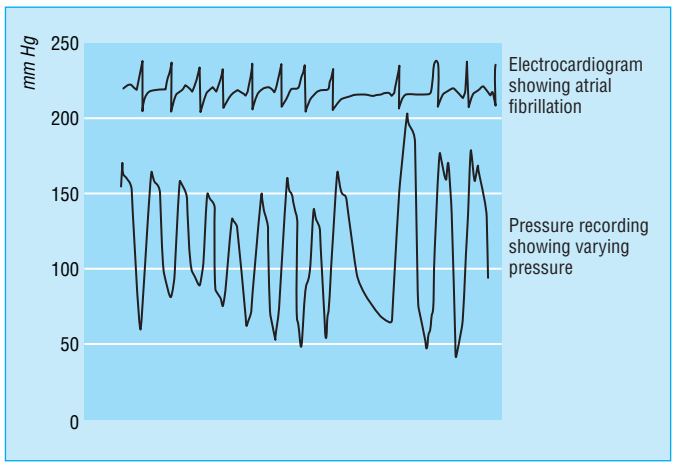
Ambulatory blood pressure measurement in a patient with hypotension. Plot and report generated by dabl ABPM— © dabl 2006 (www.dabl.ie)

International Diabetes Federation's consensus worldwide definition of metabolic syndrome (2005)

- Central obesity—waist ≥94 cm in men and ≥80 cm in women for Europids (figures available for other races)
- Two of the following:
  - —Raised triglycerides—≥1.7 mmol/l (or treatment)
  - —Low levels of high density lipoprotein cholesterol—<1.04 mmol/l in men and <1.29 mmol/l in women (or treatment)
  - —High blood pressure—≥130/85 mm Hg (or treatment)
  - —Fasting hyperglycaemia—glucose ≥5.6 mmol/l or previous diagnosis of diabetes or impaired glucose tolerance

Devices for measuring blood pressure vary greatly in their ability to accurately record blood pressure in patients with arrhythmias. Measurements of blood pressure at best will constitute a rough estimate in those with atrial fibrillation, particularly when the ventricular rhythm is rapid or highly irregular, or both. The rate of deflation should be no faster than 2 mm Hg per heartbeat, and repeated measurements may be needed to overcome variability from beat to beat.

Two potential sources of error exist when patients have bradyarrhythmia. If the rhythm is irregular, the same problems as with atrial fibrillation will apply. When the heart rate is extremely slow—for example 40 beats per minute—it is important that the rate of deflation used is less than for people with normal heart rates, as too rapid deflation will lead to underestimation of systolic blood pressure and overestimation of diastolic blood pressure.



Atrial fibrillation

Pregnancy

Clinically relevant hypertension occurs in more than 10% of pregnant women in most populations. High blood pressure is a key factor in medical decision making in pregnancy. Disappearance of sounds (fifth phase) is the most accurate measurement of diastolic pressure, except when sounds persist to zero, in which case the fourth phase of muffling of sounds should be used.

Patients who take antihypertensive drugs

In patients who take antihypertensive drugs, the timing of measurement may have a substantial influence on the blood pressure. The time of taking antihypertensive drugs should be noted.

Blood pressure in patients who are exercising

Systolic blood pressure increases with increasing dynamic work as a result of increasing cardiac output, whereas diastolic pressure usually remains about the same or moderately lower. An exaggerated blood pressure response during exercise may predict development of future hypertension.

Taking the blood pressure of a pregnant woman