Blood pressure measurement

EOIN O'BRIEN, KEVIN O'MALLEY

Summary
Blood pressure measurement, one of the most used measurements in clinical practice, is often performed carelessly. The clinical consequences of inaccurate measurement of blood pressure include misdiagnosis, inappropriate treatment and failure to prevent the cardiovascular consequences of high blood pressure. This review concentrates on the conventional technique of blood pressure measurement using a mercury sphygmomanometer, which remains the most accurate device for measuring blood pressure. The major sources of error are inadequate observer training, sphygmomanometer inaccuracy, and poor technique.

Conventional blood pressure measurement will remain the most important technique for the detection of patients who may have elevated blood pressure but before diagnostic and therapeutic decisions are made, blood pressure behaviour over time in the patient's own environment should be made. This is most effectively achieved by 24-hour recording of blood pressure.

Special consideration should be given to blood pressure measurement in obese patients, those with arrhythmias, children, pregnancy and the elderly. The London School of Hygiene Sphygmomanometer and the Hawksley random zero sphygmomanometer, which were devised for hypertension research, have each been shown to be inaccurate and can no longer be recommended.

There are many techniques for measuring blood pressure. In clinical practice, the most commonly used of these is auscultation of the Korotkov sounds during deflation of an occluding cuff attached to a mercury sphygmomanometer. In this review, most attention will be directed, therefore, to this well-established but much-misused technique. Other methods, such as oscillometry, are becoming increasingly popular and these will be given brief consideration. Developing techniques, such as plethysmography, will be mentioned but not afforded any great detail. The emphasis of this review will be on the clinical measurement of blood pressure and the mechanisms of blood pressure detection will not be considered.

The CONVENTIONAL TECHNIQUE OF BLOOD PRESSURE MEASUREMENT

The measurement of blood pressure in clinical practice is dependent on the accurate transmission and interpretation of a signal (Korotkov sound or pulse wave) from a subject via a device (the sphygmomanometer) to an observer. The successful outcome of this complex interaction requires that the observer is competent in performing the technique of blood pressure measurement. The procedure is fraught with sources of potential error which may arise in the observer, the subject, the sphygmomanometer or in the overall application of the technique.

The Observer

It is logical to open discussion with the observer, who in practice may be a doctor, nurse, health worker or even a patient. Whereas it is accepted without reservation that patients, paramedical personnel, and, perhaps to a lesser degree, nurses must receive detailed instruction in blood pressure measurement, in medical schools the student, after some theoretical instruction, is expected to 'acquire' the necessary skills for the performance of the technique. We have, therefore, two problems: first, to determine what constitutes adequate training and, second, to devise a means of assessing the efficacy of that training.

Observer error

In 1964, Geoffrey Rose and his colleagues classified observer error into three categories: systematic error, terminal digit preference and observer prejudice.¹ Systematic error, may be caused by lack of mental concentration, deteriorating auditory acuity, confusion of auditory and visual cues etc., but the most important factor is failure to interpret accurately the Korotkov sounds, especially for diastolic pressure. Terminal digit preference refers to the phenomenon whereby the observer rounds off the pressure reading to a digit of his or her choosing, most often to zero.

Observer prejudice or bias is the practice whereby the observer simply adjusts the pressure to meet his or her preconceived notion of what the pressure should be.

Training techniques

Various methods and techniques have been used to achieve greater accuracy in blood pressure measure-
The sphygmomanometer is an indispensable piece of diagnostic medical equipment. The mercury sphygmomanometer has served us well since blood pressure measurement was first introduced into clinical practice.4 Using the BHS film combined with direct observer measurements within 5mm Hg of each other for both systolic and diastolic pressure. These include direct instruction, manuals and booklets, audiotapes and video-films. Of these, the most effective combination is direct instruction using a video-film. Video-films generally use the method devised by Wilcox2 which consists of a series of blood pressure recordings in which a mercury column is seen falling in concert with recorded Korotkov sounds. The observer is required to record the level of mercury in the column corresponding to the systolic and diastolic pressures. A number of the recordings are duplicated unknown to the trainee observer so that within-observer reliability can be tested. The reference pressure is determined from the mean scores of a number of expert observers.

Recently, the Working Party on Blood Pressure Measurement of the British Hypertension Society (BHS) produced a film3 which incorporates the method just described but, in addition, the first part of the film is devoted to a visual presentation of the BHS Recommendations of blood pressure measurement.4 Using the BHS film combined with direct instruction we have been able to bring paired nurse observer measurements within 5mm Hg of each other for both systolic and diastolic pressure.

The Sphygmomanometer

The sphygmomanometer is an indispensable piece of diagnostic medical equipment. The mercury sphygmomanometer has served us well since blood pressure measurement was first introduced into clinical practice, but all too often its continuing efficiency is taken for granted. An aneroid manometer may be substituted for the mercury column but is generally not as reliable.5 Both devices are used to measure blood pressure by auscultation and a stethoscope is also required. There are many semi-automated and automated devices on the market but few of these have been adequately tested for accuracy and reliability and those which have been evaluated have been shown generally to be too inaccurate for clinical practice.5

Mercury sphygmomanometer

The mercury sphygmomanometer is the simplest, most accurate and most economical device for the indirect measurement of blood pressure6 and stands, at the time of writing, as the recommended device for the clinical measurement of blood pressure. It can be maintained and serviced easily without having to be returned to the supplier but users should be aware to the hazards associated with handling mercury.8 The following criteria must be fulfilled so as to obtain the most accurate measurements with a mercury sphygmomanometer:9

- The top of the mercury meniscus should rest at exactly zero without pressure applied; if it is below this, mercury needs to be added to the reservoir.
- The scale should be clearly calibrated in 2mm divisions from 0 to 300 mm Hg and should indicate accurately the differences between the levels of mercury in the tube and in the reservoir.
- The diameter of the reservoir must be at least 10 times that of the vertical tube, or the vertical scale must correct for the drop in the mercury level in the reservoir as the column rises.

- Substantial errors may occur if the manometer is not kept vertical during measurement. Calibrations on floor models are especially adjusted to compensate for the tilt in the face of the gauge. Stand mounted manometers are recommended for hospital use. This allows the observer to adjust the level of the sphygmomanometer and to perform measurement without having to balance the sphygmomanometer precariously on the side of the bed.
- The air vent at the top of the manometer must be kept patent as clogging will cause the mercury column to respond sluggishly to pressure changes and to overestimate pressure.
- The control valve is one of the commonest sources of error in sphygmomanometers and when it becomes defective it should be replaced.10 Spare control valves should be available in hospitals and a spare control valve should be supplied with sphygmomanometers.

Aneroid manometers

Aneroid sphygmomanometers register pressure through a bellows and lever system which is mechanically more intricate than the mercury reservoir and column. Their accuracy is affected by the jolts and bumps of everyday use and they lose accuracy over time leading usually to falsely low readings and a consequent underestimation of blood pressure. They are less accurate than mercury sphygmomanometers. Aneroid sphygmomanometers must be checked every six months against an accurate mercury sphygmomanometer over the entire pressure range. This may be done by connecting the aneroid sphygmomanometer with a Y piece to the tubing of mercury sphygmomanometer and inflating the cuff around a bottle or cylinder.11 If inaccuracies or other faults are found, the instrument must be returned to the manufacturer or supplier for repair.

Semi-automated and automated devices

One consequence of the increased interest in blood pressure measurement has been the creation of a large market for blood pressure measuring devices. A number of semi-automated devices based on Korotkov sound detection are available. An electronic microphone shielded from extraneous noise in the pressure cuff is used to detect the Korotkov sounds and blood pressure may be recorded on a chart, or indicated on a digital display. The microphones are sensitive to movement and friction, however, and may be difficult to place accurately. Manual or automatic inflation and deflation, or both, may be available. In recent years, the number of devices available commercially has risen rapidly but most have been shown to be inaccurate when compared against the mercury sphygmomanometer.6,12,13 Though some have been found to be satisfactory.14 Most semi-automated devices work on one of three principles — the detection of Korotkov sounds by a microphone or the detection of arterial blood flow by ultrasound or oscillometry.15 Other techniques which have been tried or are being developed include the phase-shift method; infrasound recording; wideband external pulse recording; plethysmography, tonometry and ultrasound,16 but as with other automated devices the results of valida-

tion have often been disappointing. At present there is no obligation on manufacturers to comply with the few recommended standards that are available.

The Cuff and Bladder

The cuff is an inelastic cloth that encircles the arm and encloses the inflatable rubber bladder. It is secured round the arm most commonly 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. Tapering cuffs should be long enough to encircle the arm several times: the full length should extend beyond the end of the inflatable bladder for 25 cm and then should gradually taper for a further 60 cm. Velcro surfaces must be effective, and when they lose their grip, the cuff should be discarded. It should be possible to remove the bladder from the cuff so that the latter can be washed from time to time.

The inflatable bladder

Of the many controversial issues in hypertension few can rival that of determining the optimal bladder dimensions for a particular arm circumference. It is fair to say that a review of the sizable literature on the subject often serves to confuse rather than clarify.

It is generally agreed that the width of the bladder is not as critical as the length, provided bladder length is adequate and the bladder is not excessively narrow. For most adult arms, a width of 12 to 14 cm is adequate. The main argument centres on bladder length. The so-called ‘standard’ cuff containing a bladder with dimensions of 12 × 23 cm is recommended for non-obese arms by the American Heart Association, and that cuffs containing larger bladders be used in obese subjects. However, the overwhelming opinion from the literature is for bladders with greater lengths (32 to 42 cm) so that the arm is encircled by the bladder in most subjects.

The American Heart Association recommends that five cuffs should be available for blood pressure measurement. However justifiable these recommendations may be on theoretical grounds, the provision of such a large variety of cuff sizes is clearly not feasible in practice. Moreover, these recommendations incorporate measurement of the arm circumference as a fundamental feature of blood pressure measurement which, it may be argued, is already a complex enough technique. The recommendations may be further faulted on the basis that most adult arms will not readily accommodate cuffs containing bladders with widths exceeding 13 cm, because the cuff encroaches on the antecubital fossa and interferes with auscultation.

The British Hypertension Society and the British Standards Institution have each decided to simplify matters by recommending only three cuffs for routine clinical use with the proviso that for very large arms care should be taken to ensure that the centre of the bladder is placed over the brachial artery. All cuffs should be imprinted with a clear white line indicating the centre of the inflatable bladder. This recommendation has taken account of the occurrence of arm size in the adult population and it has been calculated that a cuff containing a bladder 35 cm long would encircle 99% of adult arms.

### Recommended bladder dimensions

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Subject</th>
<th>Maximum arm Circumference</th>
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<tbody>
<tr>
<td>13 × 4</td>
<td>Small children</td>
<td>17 cm</td>
</tr>
<tr>
<td>18 × 8</td>
<td>Medium sized children</td>
<td>26 cm</td>
</tr>
<tr>
<td>35 × 12.5</td>
<td>Grown children and adults</td>
<td>42 cm</td>
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</table>

Accurate readings may be obtained in adults with arm circumferences greater than 42 cm by placing a cuff with a 35 cm bladder so that the centre of the bladder is over the brachial artery.

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Inflation-deflation system

The inflation-deflation system consists of an inflating and deflating mechanism connected by rubber tubing to an occluding bladder. Automated devices, of which there are many varieties, operate on the principle that once the device has been activated, it inflates automatically to a programmed cuff pressure and then deflates automatically sensing the blood pressure most commonly with a microphone, but increasingly by oscillometry and ultrasound. The recorded pressure may then be stored and/or displayed on a screen or printed.

The standard mercury and aneroid sphygmomanometers used in clinical practice are operated manually with inflation being effected by means of a bulb compressed by hand and deflation by means of a release valve which is also controlled by hand. The pump and control valve are connected to the inflatable bladder and thence to the sphygmomanometer by rubber tubing.

Rubber tubing: Leaks due to cracked or perished rubber make accurate measurement of blood pressure difficult, because the fall in mercury cannot be controlled. The rubber should be in a good condition and free from leaks. The minimum length of tubing between the cuff and the manometer should be 70 cm and between the inflation source and the cuff the tubing should be at least 30 cm in length. Connections should be airtight and easily disconnected.

Control valve: One of the most common sources of error in sphygmomanometers is the control valve, especially when an air filter rather than a rubber valve is used. When defective, it may cause leakage, making it difficult to control the release of pressure, which thus leads to underestimation of systolic and overestimation of diastolic pressures. The filter in the valve may become blocked with dirt, which demands excessive squeeze on the pump. The control valve should allow the passage of air without excessive effort; when closed, it should hold the mercury at a constant level, and when released it should allow a controlled fall in the level of mercury. Faults in the control valve may be corrected easily and cheaply, sometimes by simply cleaning the filter or alternatively by replacing the control valve.

Maintenance

Mercury sphygmomanometers are easily checked and maintained but care should be taken when handling mercury. Mercury sphygmomanometers need cleaning and checking at least every six months in hospital use and every 12 months in general practice.
Stethoscope
The stethoscope should be of high quality, one in good condition, with clean, well-fitting earpieces. The bell is most suited to the auscultation of low-pitched sounds, such as the Korotkov sounds, but in routine blood pressure measurement it probably does not matter much if the bell or diaphragm is used, provided the stethoscope is placed over the palpated brachial artery in the antecubital fossa. In fact, because the diaphragm covers a greater area and is easier to hold than a bell endpiece it is reasonable to recommend it for routine clinical measurement of blood pressure.

Technique
Blood pressure measurement is one of the few scientific measurements undertaken by doctors in the course of clinical assessment and it occupies more of the nurse's time, both on the wards, in the accident and emergency department and in the out-patients' departments, than any other measurement. The situation is similar in family practice. The consequences of decisions arising from the measurement of blood pressure may be crucial to patient management both in the short-term and, perhaps more importantly, the level of blood pressure recorded may influence the quality of existence for the remainder of a patient's life. It follows, therefore, that considerable care should be given to the technique of blood pressure measurement. The following guidelines to performing the technique are drawn mostly from the ABC of Hypertension and the British Hypertension Society Recommendations on Blood Pressure Measurement.

Variability of blood pressure
The observer must be aware of the considerable variability that may occur in blood pressure from moment to moment with respiration, emotion, exercise, meals, tobacco, alcohol, temperature, bladder distension, and pain, and that blood pressure is also influenced by age, race and circadian variation. It is not always possible to modify these many factors, but we can minimise their effect by taking them into account in reaching a decision as to the relevance or otherwise of a particular blood pressure measurement.

Insofar as is practical, the patient should be relaxed in a quiet room which is at a comfortable temperature and a short period of rest should precede the measurement. When it is not possible to achieve optimum conditions, this should be noted with the blood pressure reading — for example, 'BP 154/92, R arm, phase V (patient very nervous)'.

The defence reaction: 'white coat hypertension'
Anxiety raises blood pressure, often by as much as 30 mm Hg. The defence or alarm reaction is a rise in blood pressure associated with blood pressure measurement. This increase in blood pressure may subside once the subject becomes accustomed to the procedure and the observer, but in many subjects blood pressure is always higher when measured by doctors, and to a lesser degree by nurses — so-called 'white coat hypertension'.

Explanation to subject
The first step, therefore, in blood pressure measurement is adequate explanation of the procedure in an attempt to allay fear and anxiety, especially of nervous subjects. In particular, subjects having blood pressure measured for the first time should be told that there is minor discomfort caused by inflation of the cuff.

Attitude of observer
The observer should have been trained as discussed previously. Before taking the blood pressure, he or she should be in a comfortable relaxed position. If the observer is hurried, the pressure will be released too rapidly with underestimation of systolic and overestimation of diastolic pressures. If there is interruption, the exact measurement may be forgotten and an approximation made. Therefore, the blood pressure should be written down as soon as it has been measured as relying on memory may result in error.

Posture of subject
Posture affects blood pressure with a general tendency for it to increase from the lying to sitting or standing position. However, in most people posture is unlikely to lead to significant error in blood pressure measurement provided the arm is supported at heart level. Nonetheless, it is advisable to standardise posture for individual patients and in practice blood pressure is usually measured in the sitting position. Patients should be comfortable whatever their position. No information is available on the optimal time that a subject should remain in a particular position before a measurement, but three minutes is suggested for the lying and sitting positions and one minute standing. Some antihypertensive drugs cause postural hypotension, and when this is expected, blood pressure should be measured both lying and standing.

Arm support
If the arm in which measurement is being made is unsupported, as tends to happen if the subject is sitting or standing, isometric exercise is performed raising blood pressure and heart rate. Diastolic blood pressure may be raised by as much as 10% by having the arm extended and unsupported during blood pressure measurement. The effect of isometric exercise is greater in hypertensive patients and in those taking beta-adrenoceptor blocking drugs. It is essential, therefore, that the arm is supported during blood pressure measurement and this is best achieved in practice by having the observer hold the subject's arm at the elbow though in research the use of an arm support on a stand has much to commend it.

Arm position
Not alone should the arm be supported, but it must also be horizontal at the level of the heart, as denoted by the mid-sternal level. Dependency of the arm below heart level leads to an overestimation of systolic and diastolic pressures and raising the arm above heart level leads to underestimation of these pressures. The magnitude of this error can be as great as 10 mm Hg for systolic and diastolic pressures. This source of error becomes especially important in the sitting and standing positions when the arm is likely to be dependent by the subject's side. However, Ljungvall et al have recently demonstrated that even in the supine position an error 5.5 mm Hg for diastolic pressure may occur if the arm is not supported at heart level.
Which arm
The significance of the difference in blood pressure between arms has been the subject of debate for over fifty years. However, early studies showing differences between arms used sequential measurement and subsequent studies using simultaneous, rather than sequential measurement of blood pressure, have tended to show no significant difference between arms. A reasonable policy is to measure blood pressure in both arms at the initial examination, and if differences greater than 20 mm Hg for systolic or 10 mm Hg for diastolic pressure are present on three consecutive readings simultaneous measurement should be carried out to determine if the difference is real or artefactual. This is done by two trained observers recording the blood pressure simultaneously in both arms using one sphygmomanometer connected by a Y connector to two occluding cuffs. When there is a difference between arms, a cause should be sought and in the absence of any being found, blood pressure should be recorded thereafter in the arm with the highest pressure on the basis that the cardiovascular system may be subject to the adverse effects of the higher rather than the lower pressure.

Application of the cuff
Bulky, tight or restrictive clothing should be removed from the arm. If a blouse, shirt, or pyjama jacket is worn, it is better to leave the cloth under the cuff rather than roll the sleeve into a constricting band. If the cuff is not applied snugly to the arm, falsely high blood pressure will be recorded, and if the cuff is too tight, errors may also occur. The cuff should be wrapped round the arm ensuring that the bladder completely encircles the arm, the centre of the bladder must be over the brachial artery. The rubber tubes from the bladder are usually placed inferiorly, often at the site of the brachial artery, but it is now recommended that they should be placed superiorly or, with completely encircling bladders, posteriorly, so that the antecubital fossa is easily accessible for auscultation. The lower edge of the cuff should be 2-3 cm above the point of brachial artery pulsation.

Position of manometer
The observer should be no further than three feet from the manometer so that the scale can be read easily. The mercury manometer has a vertical scale and errors will occur unless the eye is kept close to the level of the meniscus. The aneroid scale is a composite of vertical and horizontal divisions with numbers and must be viewed straight on with the eye on a line perpendicular to the centre of the face of the gauge. The mercury column should be vertical (some models are designed with a tilt) and at eye level — this is achieved most effectively with stand-mounted models which can be easily adjusted to suit the height of the observer.

Palpatory estimation of blood pressure
The brachial artery should be palpated while the cuff is rapidly inflated to about 30 mm Hg above the disappearance of the pulse and then slowly deflated. The observer should note the pressure at which the pulse reappears. This is the approximate level of the systolic pressure, and because Phase I sounds sometimes disappear as pressure is reduced and reappear at a lower level (the auscultatory gap), the systolic pressure may be underestimated unless already determined by palpation. The palpatory technique is also useful in patients in whom auscultatory end points may be difficult to judge accurately — for example, pregnant women, patients in shock, or those taking exercise. (The radial artery is often used for palpatory estimation of the systolic pressure, but by using the brachial artery the observer also establishes its location before auscultation.)

Auscultatory measurement of systolic and diastolic pressures
The stethoscope should be placed gently over the brachial artery at the point of maximal pulsation. A bell end-piece gives better sound reproduction, but in clinical practice, a diaphragm is easier to secure with the fingers of one hand and covers a large area. The stethoscope should be held firmly and evenly, but without excessive pressure. Too much pressure may distort the artery, producing sounds below diastolic pressure. To avoid friction sounds, the stethoscope end-piece should not touch the clothing, cuff, or rubber tubes.

The cuff should then be inflated rapidly to about 30 mm Hg above the palpated systolic pressure and deflated at a rate of 2 to 3 mm Hg per pulse beat (or per second) during which the auscultatory phenomena described below will be heard. When all sounds have disappeared, the cuff should be deflated rapidly and completely before repeating the measurement to prevent venous congestion of the arm. The following phases, first described by Nicolai Korotkow, may now be heard:

- **Phase I** — The first appearance of faint, repetitive, clear tapping sounds which gradually increase in intensity for at least two consecutive beats is the systolic blood pressure.
- **Phase II** — A brief period may follow during which the sounds soften and acquire a swishing quality.
- **Phase III** — The return of sharper sounds, which become crisper but never fully regain the intensity of Phase I sounds. The clinical significance, if any, to phases II and III has not been established.
- **Phase IV** — The distinct abrupt muffling of sounds, which become soft and blowing in quality.
- **Phase V** — The point at which all sounds finally disappear completely is the diastolic pressure.

Diastolic dilemma
Recommendations on blood pressure measurement have vacillated for many years on the issue of the diastolic end-point — the so-called diastolic 'dilemma'. Phase IV (muffling) may coincide with or be as much as 10 mm Hg higher than Phase V (disappearance), but usually the difference is less than 5 mm Hg. Phase V correlates best with intra-arterial pressure, but general acceptance of the silent end-point has been resisted until recently because in some groups of patients, for example, children and pregnant women, anaemic or elderly patients, in whom the silent end-point may be greatly below the muffling of sounds. In some patients, sounds may be audible when cuff pressure is deflated even to zero. The arguments for and against selecting one phase over the other have been well summarised but there is now a general consensus that disappearance...
Recording blood pressure

The blood pressure should be written down as soon as it has been recorded. Measurements of systolic and diastolic pressure should be made to the nearest 2 mm Hg and rounding off to the nearest 5 or 10 mm Hg (digit preference) is not permissible. The arm in which the pressure is being recorded and the position of the subject should be denoted and on the first attendance pressures should be recorded in both arms. In obese patients, the bladder size should be indicated. If, as so often happens in practice, the observer has to make do with a 'standard' cuff containing a bladder with the dimensions 23 × 12 cm, it is best to state that measurement was made with such a cuff so that the presence of 'cuff hypertension' can be taken into account in diagnostic and management decisions and so that arrangements can be made for a more accurate measurement of blood pressure. In clinical practice, the diastolic pressure should be recorded as Phase V, except in those patients in whom sounds persist greatly below muffling and in pregnant women, in whom Phase IV should be recorded, but this should be clearly indicated. In hypertension research we recommend that both Phases IV and V be recorded. If the patient is so anxious, restless or distressed so as to influence blood pressure behaviour, this should be recorded with the blood pressure. The presence of an auscultatory gap should always be indicated.

Finally, in patients taking blood pressure lowering drugs, the optimum time for control of blood pressure will depend on the time of day at which the drugs are taken. It may be helpful, therefore, when assessing the effect of antihypertensive drugs, to note the time of drug ingestion in relation to the time of measurement.

A comprehensive recording of blood pressure in two clinical situations might, therefore, appear as follows:

(a) — R. arm 154/82; L. arm 148/76; 35 cm bladder; sitting; subject anxious.
(b) — R. arm 210/52; L. arm 204/48 (phase IV/Auscultatory gap); 35 cm bladder; lying; 182/60 standing; medication at 8.00 hours/BP at 9.30 hours.

Number of measurements

It is recommended that one measurement be taken carefully at each visit, repeating the measurement if there is uncertainty or distraction, rather than making a number of hurried measurements. In patients in whom sustained increases of blood pressures are being assessed a number of measurements should be made on different occasions over a number of weeks or months before diagnostic or management decisions are made.

Obtaining a blood pressure profile

Accurate though measurement may be, when the above recommendations are followed, it should be realised that any such measurement represents only a fraction of the 24-hour blood pressure profile. Therefore, it is becoming common in clinical practice to obtain a profile of blood pressure behaviour over time before making decisions on diagnosis and treatment. The two most popular techniques are self-measurement and ambulatory measurement, though repeated measurements may also give some indication of blood pressure behaviour.

Key points in measuring blood pressure

- Have the subject seated comfortably.
- Check the sphygmomanometer (meniscus at zero, tubing airtight, etc.)
- Remove restrictive clothes from arm.
- Make sure bladder is adequate length.
- Apply cuff snugly (lower edge 2-3 cm above fossa)
- Palpate brachial artery pulsation.
- Inflate cuff above disappearance of pulse.
- Deflate cuff slowly and note point of reappearance of pulse.
- Place stethoscope gently over point of maximal pulsation.
- Inflate cuff to 30 mm Hg above palpated systolic pressure.
- Reduce pressure at rate of 2-3 mm Hg per beat or per second.
- Take reading of systolic pressure when repetitive, clear tapping sounds appear for two consecutive beats.
- Take readings of diastolic pressure when repetitive sounds disappear.
- Write down measurement immediately.

OBTAINING A PROFILE OF BLOOD PRESSURE

Self (home) measurement

Since Brown's observation in 1930 that blood pressure measured in the home was lower than that recorded by a doctor, the discrepancy between pressures recorded in the home and the clinic has been repeatedly confirmed — as has the considerable individual variability. Assessed against clinic measurements, blood pressure recorded at home is accurate whether measured by patients or their relatives or friends, and the technique can detect small average changes in blood pressure.

Why, then, has home measurement of blood pressure failed to achieve the popularity of home urinalysis in diabetes? There are a number of explanations. First, there is the problem of training the patient to measure blood pressure, though in our experience a satisfactory degree of competence can probably be achieved by using illustrated instructions; a further difficulty, which cannot easily be corrected, is that of subjective bias; the physician may be concerned about the anxiety that may result from the patient taking an obsessional interest in his or her blood pressure and, finally, most devices available for self-measurement of blood pressure have not been validated adequately or have been shown to be inaccurate. For these reasons, home measurement of blood pressure has not received widespread acceptance, though it has a useful place in carefully selected patients. Moreover, 24-hour ambulatory blood pressure measurement, by providing a more objective blood pressure profile during both the day and night and one which is also free of bias, is becoming the preferred method of assessing blood pressure behaviour.

Ambulatory blood pressure measurement

Ambulatory blood pressure measurement over 24
hours has given new insights into blood pressure behaviour and is bringing about a reappraisal of previously held concepts on hypertension. The technique is rapidly gaining acceptance as a useful procedure in the clinical management of hypertension, in the assessment of antihypertensive drugs and as a means of predicting outcome in hypertension.

Ambulatory blood pressure recording may prove to be one of the most significant developments in the clinical management of hypertension. The technique also has considerable potential in hypertension research. Undoubtedly, its greatest value is the facility to assess blood pressure behaviour over a 24- or 48-hour period in the patient’s own working and home environment. Data from ambulatory measurement suggest that many subjects are diagnosed, labelled and treated as hypertensive with conventional procedures in the home environment. Data from ambulatory measurement who might not be so diagnosed and not inappropriately treated. Translated into fiscal terms, this could represent an overexpenditure on antihypertensive drugs in the region of 5 billion dollars annually in the United States.

Ambulatory blood pressure measurement, moreover, by providing a 24-hour profile of blood pressure, facilitates the prescribing of antihypertensive medication to suit the requirements of the individual patient and further reduces the cost of medication.

The increasing use of 24-hour ambulatory blood pressure measurement in clinical practice has shown a number of patterns of blood pressure behaviour, such as the ‘white coat’ effect whereby the circumstances of measurement may in themselves induce a rise in blood pressure.

BLOOD PRESSURE MEASUREMENT IN SPECIAL CIRCUMSTANCES

Obesity
The association between obesity and hypertension has been confirmed in many epidemiological studies and has at least two components. First, there appears to be a pathophysiological connection and it may well be that in some cases the two conditions are causally linked. The second is more pertinent to the present context in that obesity, if not taken into account, may result in inaccurate blood pressure values being obtained by indirect measurement techniques. The relationship of arm circumference and bladder dimension has been discussed above.

Arrhythmias
The major source of difficulty in blood pressure measurement in arrhythmias is, that when cardiac rhythm is irregular, there is a large variation in blood pressure from beat to beat. Thus, in arrhythmias, such as atrial fibrillation, stroke volume, and, as a consequence, blood pressure varies depending on the preceding pulse interval. Secondly, in such circumstances, there is no generally accepted method of determining auscultatory end-points. The lack of a uniform approach is reflected by greater interobserver variability when blood pressure is measured in atrial fibrillation than in sinus rhythm.

In bradyarrhythmias there may be two sources of error. First, if the rhythm is irregular, the same problems as with atrial fibrillation will apply. Secondly, when the heart rate is extremely slow, for example, 40 beats per minute, it is important that the deflation rate used is less than for normal heart rates as too rapid deflation will lead to underestimation of systolic and overestimation of diastolic pressure.

Children
Blood pressure measurement in children presents a number of difficulties. Blood pressure variability is greater than in adults and thus any one reading is less likely to represent the true blood pressure in children. Also increased variability confers a greater tendency for regression towards the mean. Conventional sphygmomanometry is recommended for general use but systolic pressure is preferred to diastolic because of greater accuracy and reproducibility.

Cuff dimensions are most important and three cuffs with bladders measuring 4 x 13 cm, 8 x 18 cm and the adult dimensions 12 x 35 cm are required for the range of arm sizes likely to be encountered in the age range 0-14 years. The widest cuff practicable should be used. Korotkov sounds are not reliably audible in all children under one year and in many under five years of age. In such cases, conventional sphygmomanometry is impossible and more sensitive methods of detection such as doppler, ultrasound or oscillometry must be used.

Pregnancy
Between 2% and 5% of pregnancies in Western Europe are complicated by clinically relevant hypertension, and in a significant number of these raised blood pressure is a key factor in medical decision making in the pregnancy. Particular attention must be paid to blood pressure measurement in pregnancy because of the important implications for patient management, as well as the fact that blood pressure measurement in pregnancy presents some special problems.

As with essential hypertension and normotensives there are discrepancies between intra-arterial blood pressure values and those obtained by indirect measurement. However, it appears that this is not sufficient to invalidate decisions made on the basis of conventional clinical measurement.

Blood pressure levels are markedly affected by body position, particularly in the third trimester. Both systolic and diastolic pressures are about 10 mm Hg lower in the left lateral recumbent position than in the sitting, supine and erect positions. Despite the documented importance of maternal position and the differences that may be found between Phases IV and V in pregnancy, there is considerable variation in the practice employed to measure blood pressure. Various positions are used and there is even lack of agreement as to the Korotkov phase for diastolic blood pressure, though Phase V is generally recommended.

Elderly
Blood pressure as measured in epidemiological and interventional studies predicts morbidity and mortality in the elderly as effectively as in the young. The extent to which blood pressure conventionally measured predicts outcome may be influenced, not
only by the strength of the association between raised blood pressure and outcome but also on various factors that influence the accuracy of blood pressure measurement and the extent to which casual blood pressure represents the blood pressure load on the heart and circulation.

Inaccuracy of the technique of measurement may result in blood pressure values being found that are at variance with the true blood pressure at the time of measurement and increased variability may affect the likelihood of a reading(s) being representative of blood pressure over time.

Of the pathophysiological changes that characterise hypertension in the elderly, none is more apparent than the tendency to have raised systolic blood pressure and this finds its extreme form in isolated systolic hypertension. There is a decrease in the elasticity and distensibility of the ageing blood vessels due to changes in smooth muscle proliferation and alterations in elastin, collagen and calcium content leading to a decrease in compliance. One consequence of this is the increase of systolic blood pressure found in elderly hypertensives. A second consequence is that the decrease in compliance may interfere with the accuracy of indirect sphygmomanometry in the elderly. Indirect blood pressure measurement may overestimate blood pressure in the elderly. The term 'pseudohypertension' has been used to describe this phenomenon. True hypertension and 'pseudohypertension' may be differentiated by the use of Osler's manoeuvre. William Osler observed that if, after a blood pressure cuff is inflated above systolic pressure, the artery remains palpable distal to the cuff the vessel is likely to be sclerosed. Patients in whom Osler's sign is positive have stiff arteries and a greater degree of 'pseudohypertension'.

Our studies have led us to conclude that the standard technique for blood pressure measurement with a mercury sphygmomanometer is as accurate in the elderly as in young patients in general. However, that is not to say that there are not some elderly hypertensive patients — prevalence unknown — who have a large disparity between direct and indirect blood pressure measurement and in such circumstances conventional sphygmomanometry may overestimate both systolic and diastolic blood pressure.

As blood pressure variability is increased in the elderly blood pressure measurement is less reliable in the older patient. Therefore, the likelihood of any one reading being representative of blood pressure in general diminishes. To a greater or lesser extent, this problem pertains in all patients due to various sources of variability including diurnal patterns, white coat effect, anxiety, cold, etc. One way of reducing the impact of the increased variability is to carry out repeated measurements; 24 hour ambulatory blood pressure measurement can give valuable information in elderly patients.

Two extreme forms of blood pressure change in the elderly are postural hypotension and postprandial hypotension. It is possible for postural hypotension to coexist with raised supine and sitting blood pressure and it is important that blood pressure is assessed in these positions as well as standing on initial assessment and, from time to time, if drugs known to cause postural hypotension are being taken. These include not only blood pressure lowering drugs, such as diuretics, but also non-cardiovascular drugs, for example, neuroleptics and tricyclic antidepressants. Elderly patients get quite a marked blood pressure fall after eating and this may be symptomatic. Again, this can only be diagnosed definitively by measuring blood pressure when standing after a meal.

Blood pressure measurement in critical care units

Complex devices that record blood pressure automatically at preset intervals have been designed for intensive care units and theatres. These devices often use two methods of measurement, most commonly Korotkow sound detection and oscillometry, but often the mode being used is not indicated and assessments of accuracy for each mode are sometimes not available from the manufacturers. Moreover, these devices do not always lend themselves to independent assessment because of their complex design.

Blood pressure measurement in research

Blood pressure measurement by an observer using a standard mercury sphygmomanometer and stethoscope is subject to observer prejudice and terminal digit preference. These limitations can introduce error which is unacceptable for research work. However, careful training of observers as described above can greatly reduce the error. Two devices have been designed specifically for research use — the random zero sphygmomanometer, which reduces observer prejudice, and the London School of Hygiene sphygmomanometer, which reduces both observer prejudice and terminal digit preference.

London School of Hygiene sphygmomanometer

The first such device to be introduced was the London School of Hygiene sphygmomanometer. By means of a series of columns and plungers the observer recorded pressure by depressing the appropriate plunger at the end-points for systolic pressure and phases IV and V diastolic pressure without having any means of knowing the pressure in the cuff. Rather surprisingly, the London School of Hygiene Sphygmomanometer was accepted as the 'gold standard' for blood pressure measurement without being subjected to validation. In 1982, a calibration error was demonstrated in the device which, as far as we know, has not been rectified by the manufacturers and the London School of Hygiene Sphygmomanometer is not now much used.

Random zero sphygmomanometer

In 1963, Garrow described a 'zero-muddler for unprejudiced sphygmomanomer' which was modified by Wright and Dore in 1970 and produced commercially by Messers Hawksley and Sons. It is larger than a conventional sphygmomanometer and some ten times more expensive. The manometer function is similar to the mercury sphygmomanometer but a wheel is spun before each measurement to adjust the zero to an unknown level. Once the blood pressure has been measured the level of zero may be determined and the pressure reading corrected. In this way, observer prejudice is reduced but not digit preference. This device is, generally, accepted as the instrument of choice for epidemiological and research studies because it...
Produced by the British Hypertension Society, this two part training video first outlines the points to check in assessing equipment and then provides step by step guidance on the correct procedure for blood pressure measurement. The second part displays a sequence of falling mercury sphygmomanometer columns with simultaneous Korotkoff sounds. Observers are asked to make recordings from these and can check their findings against those of a group of experienced observers. Also supplied with the video is a copy of the second edition of Blood Pressure Measurement, by J C Petrie, E T O’Brien, W A Littler, M de Swiet, P L Padfield and M J Dillon, which summarises the main points for easy reference.

**Price:** UK and abroad £24.95 (including VAT in the UK and air mail despatch abroad)

Copies of the second edition of Blood Pressure Measurement, are available separately—UK £1.25; abroad £2.25.

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reduces observer bias and obscures digit preference, though the facility of the device to reduce terminal digit preference has been questioned. Because the random-zero sphygmomanometer is, basically, a mercury sphygmomanometer, its accuracy has been accepted rather uncritically and it has replaced the London School of Hygiene Sphygmomanometer as the ‘gold standard’ against which other devices are assessed. However, recently it has been shown to systematically underestimate blood pressure, especially diastolic pressure and we have confirmed this tendency thus raising the question as to its suitability for research and epidemiological studies.

**Concluding comment**

For the future, careful measurement of blood pressure with a mercury sphygmomanometer following the above recommendations is likely to remain the most effective first line in assessing blood pressure. If conventional measurement is below 150/90 mm Hg, some clinical observations on blood pressure and their practical assessment. However, recently it has been shown to reduce observer bias and obscure digit preference, especially on a number of occasions, that individual the two arms. Med J AUS 1935: 189-191, Southby, R. Some clinical observations on blood pressure and their practical application, with special reference to variation of blood pressure readings in the two arms. Med J AUS 1935: II: 589-590.

**References**


