1981

A B C OF HYPERTENSION

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Preface

by the Editor
British Medical Journal

Doctors should be grateful for hypertension—a disorder they can recognise simply by remembering to take their patients' blood pressure and which mostly responds very well to treatment. This simplicity may be deceptive, however; measurement of the blood pressure, interpretation of the results, and the decisions that follow should all be based on comprehensive knowledge of recent advances.

Last year and this the *BMJ* published ABCs of blood pressure measurement, reduction, and management, providing that knowledge in an easily assimilable, heavily illustrated format. These articles have now been collected together to provide a practical guide for general practitioners and others who measure blood pressure and manage patients with hypertension.

STEPHEN LOCK
1981

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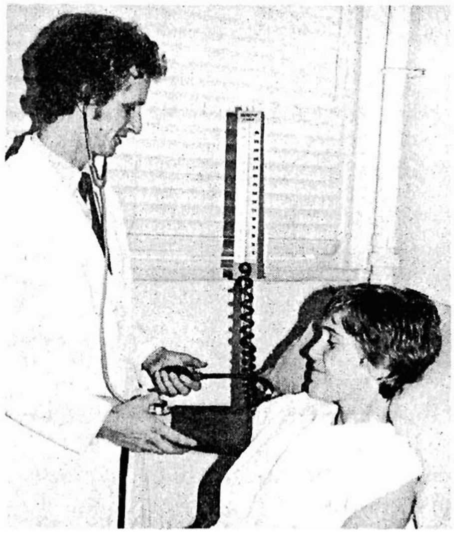
The illustration on the back cover of Stephen Hales measuring the blood pressure in a horse is reproduced from the *Medical Times* of 1944.

THE OBSERVER

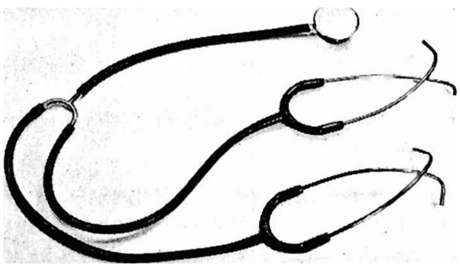
EOIN T O'BRIEN   KEVIN O'MALLEY



Apart from the stethoscope, the sphygmomanometer is probably used more than any other single instrument in both hospital and general practice. Doctors, nurses, and paramedical staff record blood pressure; and decisions on treatment, investigation, prognosis, fitness for insurance and employment, and epidemiological conclusions are based on these measurements. More recently patients themselves are being trained to record their own blood pressure, and there are now machines which record blood pressure in some shops and airports.

When blood pressure is measured by routine sphygmomanometry the reading is generally assumed to be accurate, and little thought is given to major errors that may arise through inadequate knowledge, carelessness, or poor maintenance of the instrument. Many doctors and nurses are unaware of potential errors of technique and fail to appreciate the limits of blood pressure measurement. They may therefore attach undue clinical importance to what is, at best, an inaccurate technique of measurement.

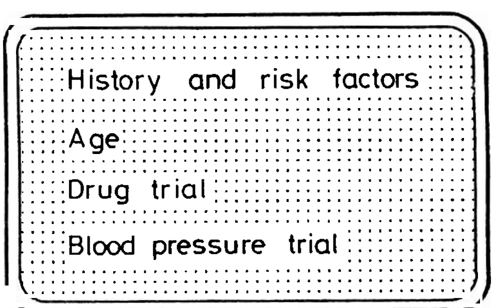
Training



There is a surprising degree of variation in blood pressure interpretation among observers. Much of the variation is probably due to failure to appreciate that if indirect sphygmomanometry is to be accurate attention to detail, especially in interpreting sounds, is essential.

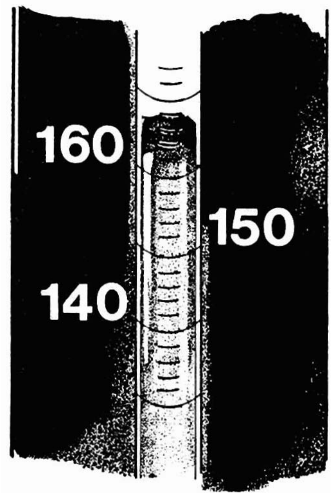
Nurses and medical students are often inadequately trained in blood pressure measurement. With increasing reliance on paramedical staff for recording blood pressure and the increasing interest in home recording of blood pressure much more attention needs to be directed towards training methods. Audiovisual techniques are ideally suited both to demonstrating and to assessing blood pressure measurement, and students should be introduced to the technique and given preliminary training by these means. For later training the binaural stethoscope is probably the most useful tool. It enables the trainee's general competence and visual and auditory competence to be assessed.

What biases the observer?



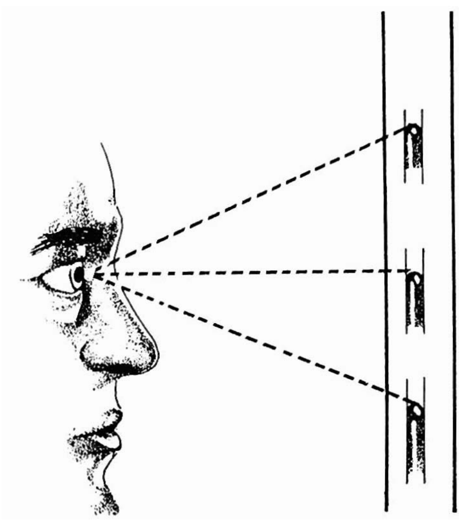
The observer is often unconsciously biased towards raising or lowering the patient's blood pressure. This is most likely to occur when there is an arbitrary division between normal and high blood pressure, such as 140/90 mm Hg. An observer might tend to record a favourable measurement in a young healthy man with a borderline increase in pressure but categorise as hypertensive an obese, middle-aged man with a similar reading. Likewise, there might be observer bias in over-reading blood pressure to include the patient in a study such as a drug trial. Adequate discussion during training to make the observer aware of this sort of bias might minimise its influence.

Terminal digit preference



Observers show a strong preference for the terminal digits 0 and 5, even though a 5-mm marking does not appear on many scales. There is some evidence that careful training may minimise this source of error; and if the observer can devote enough time to recording the blood pressure and if the scale is clearly marked the pressure may be recorded to the nearest 2 mm Hg. Special sphygmomanometers have been designed to remove terminal digit preference and observer bias, but they are generally used only for research.

Viewing distance and angle

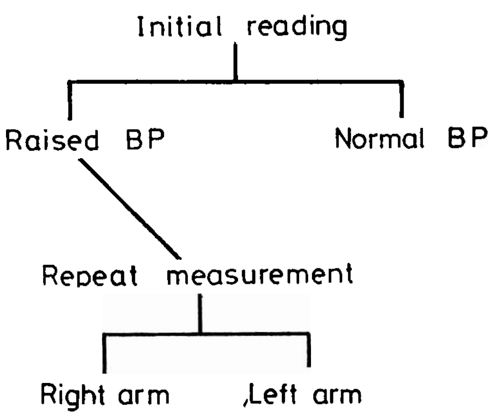


The observer should be no further than three feet from the manometer so that he can read the scale easily.

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 and numbers and must be viewed straight on—with the eye on a line perpendicular to the centre of the face of the gauge.

Taking care and time



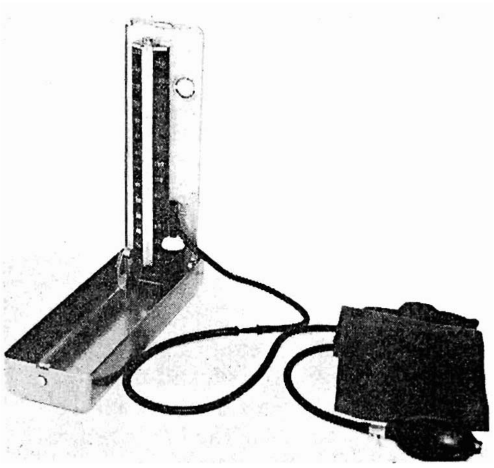
The observer should be in a comfortable relaxed position. If he is hurried he will release the pressure too rapidly and will thus underestimate the systolic pressure and overestimate the diastolic. If he is interrupted he may forget the exact measurement and estimate it, causing an inaccurate value to be recorded. The blood pressure reading should be written as soon as measured because relying on memory may result in error.

It takes about five minutes to measure blood pressure accurately, but in practice considerably less time is devoted to the procedure. If the blood pressure is raised at the initial assessment the observer should repeat the measurement and also take the blood pressure in the other arm.

Partial loss of hearing is another potential source of error. Low-energy acoustic sounds, such as the Korotkoff sounds, may be just above the normal hearing threshold when listened for with a stethoscope, and an observer may not recognise his inability to appreciate these sounds.

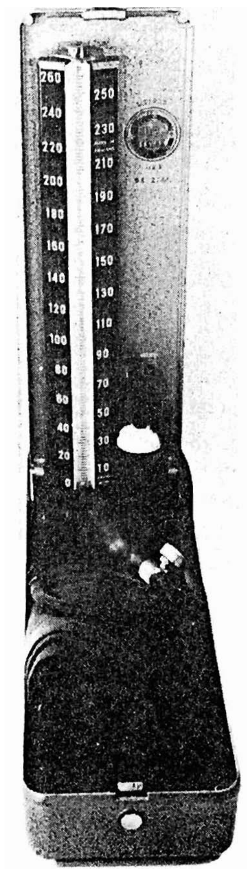
THE SPHYGMOMANOMETER

EOIN T O'BRIEN KEVIN O'MALLEY



The sphygmomanometer is an indispensable piece of medical diagnostic equipment, but all too often its continuing efficiency is taken for granted. A survey of all our hospital sphygmomanometers showed that nearly half of them were inaccurate, and similar results have been found in other hospitals. The proportion is probably little different in general practice. Few hospitals have any policy for the regular maintenance of basic equipment such as sphygmomanometers.

Mercury manometers



Mercury sphygmomanometers are reliable pieces of equipment that are easily maintained. Assessed against direct intra-arterial pressures, the standard mercury-in-glass manometer tends to slightly underestimate systolic pressure and overestimate diastolic (phase 5) pressure.

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 2-mm divisions from 0 to 300 mm Hg (we hope kilopascals will not be introduced) 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.)

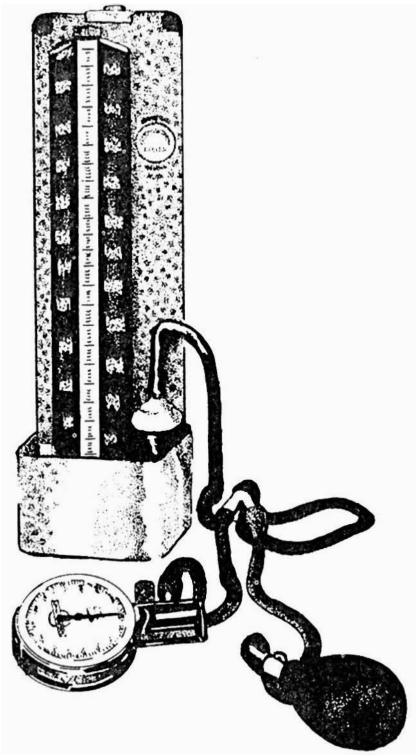
The air vent at the top of the manometer must be kept patent since clogging will cause the mercury column to respond sluggishly to pressure changes. Mercury sphygmomanometers need cleaning and checking every year.

Aneroid manometers

Aneroid sphygmomanometers have levers which can stick and are affected by jolts, and they are generally less accurate than mercury manometers. When calibrated against a mercury manometer an average deviation of 3 mm Hg is considered acceptable. Even so, some studies have shown that 30-35% of aneroid sphygmomanometers have an average deviation of over 3 mm Hg, while 6-13% deviate by 7 mm Hg or more.

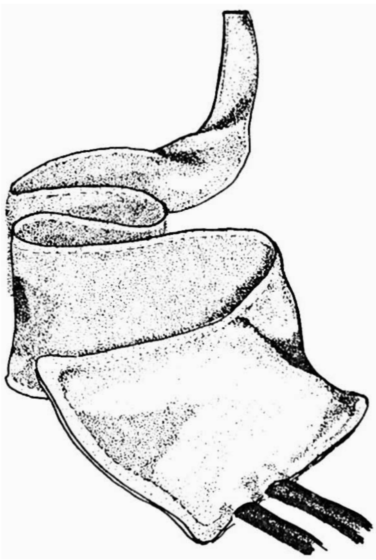
Some new aneroid sphygmomanometers incorporate a gauge which indicates when the machine is losing accuracy.

Which manometer?



The choice of sphygmomanometer should be influenced by the use to which it will be put, the care with which it will be treated, and the availability of facilities for regular maintenance. When a machine will be used by many observers and is therefore likely to be knocked or jolted, and when maintenance facilities are not available, the mercury sphygmomanometer is better than the aneroid machine. Aneroid instruments should be checked against a mercury manometer every six months, and the aneroid manometer needs to be checked throughout the entire pressure range.

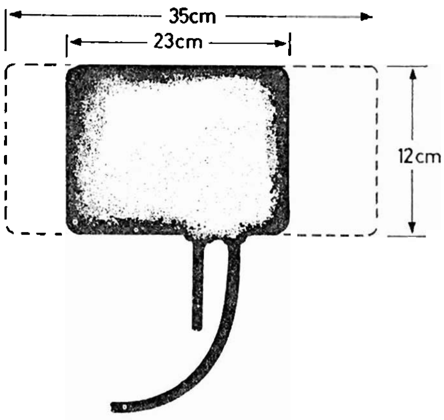
The cuff

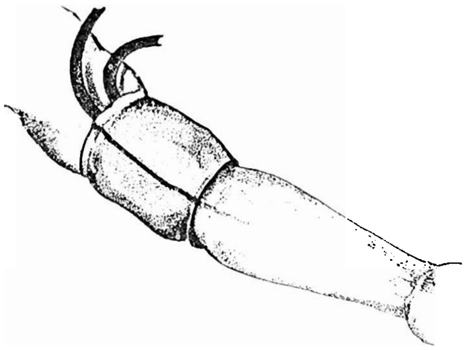


The cuff is an inelastic cloth that encircles the arm and encloses the inflatable rubber bladder. It is secured round the arm by wrapping its tapering end into the encircling cuff, by Velcro surfaces, or by hooks.

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.

The inflatable bladder





A bladder which is too short or too narrow, or both (overall too small), will give falsely high pressures, and one which is too wide or too long, or both (overall too large), will give falsely low pressures. Nevertheless, if the bladder is too wide or too narrow only a small loss of accuracy results so long as the bladder is long enough to encircle the arm completely. Readings taken with a completely encircling bladder correlate best with intra-arterial pressure.

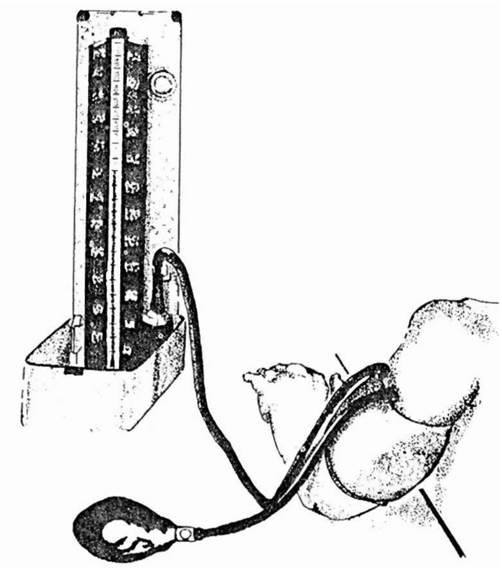
The recommended bladder width is 20% greater than (or 1·2 times) the diameter of the limb, which is equivalent to 40% of the arm's circumference. Most bladders are 12 to 13 cm wide, with those for obese arms being 15 or 16 cm, but most arms will not comfortably accommodate a cuff much wider than 13 cm.

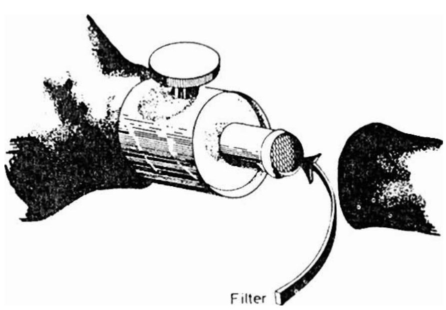
Bladder lengths vary from around 22 to 36 cm, there being different lengths for obese arms, for children's arms, and for thighs. The standard bladder (22·9 cm long) will encircle only 33% of adult arms, whereas a 36 cm bladder would encircle 99% of adult arms.

Manufacturers of blood pressure equipment must be persuaded to review bladder size. We recommend that for adults the bladder should be at least 35 cm long and 12 cm wide.

If the bladder does not encircle the arm, the centre of the bladder must be placed directly over the artery to be compressed, or the readings will be very inaccurate. Many cuffs now indicate the centre of the bladder and also indicate bladder size in relation to arm circumference.

Rubber tubing, pump, and control valve





Leaks due to cracked or perished rubber make accurate measurement of the blood pressure difficult because the fall in mercury cannot be controlled. The rubber should be in a good condition and free of leaks. The tubing should be at least 76 cm long, and connections must be airtight and easily disconnected.

The control valve is a common source of error, especially in sphygmomanometers with an air filter, rather than a rubber valve. The filter 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.

The valve may be tested by rolling a cloth cuff into its own tail or, with a Velcro cuff, matching Velcro to Velcro, and then pumping up to 200 mm Hg and waiting for 10 seconds. The mercury should not fall more than 2 mm Hg during those 10 seconds. If it does fall further the circuit should be clamped in sections to locate the leak, which is usually in the control valve. The valve should then be released slowly four times, on two of which it should be possible to control the rate of fall to 1 mm Hg per second, and to change from faster to slower rates at will. Inability to do so is usually due to air filter blockage, which may be rectified by cleaning the filter, but in practice it is usually simpler to replace the pump and control valve.

THE PATIENT

EOIN T O'BRIEN KEVIN O'MALLEY

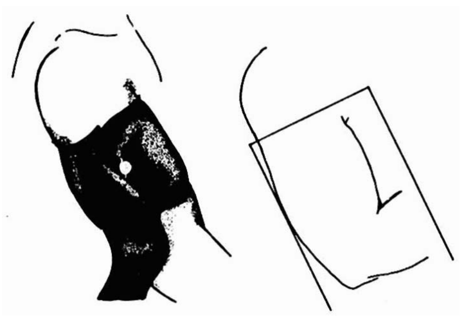
Age	Alcohol
Race	Smoking
Temperature	Exercise
Pain	Illness
Emotion	Obesity

A person's blood pressure varies from moment to moment with respiration, emotion, exercise, meals, tobacco, alcohol, temperature, bladder distension, and pain, and it is influenced by changes in circadian rhythms, age, and race. Furthermore, the patient may have physical characteristics, such as obesity, or diseases which may modify the blood pressure or make its measurement difficult or inaccurate. We cannot standardise our patients but we can minimise the effect of environmental influences by taking account of such factors.

Adequate explanation of the procedure is important to allay the fears of anxious patients. It is essential if the patient with hypertension is to take part in the management of his or her disease and adhere to treatment. Home recording of blood pressure may become an important part of management.

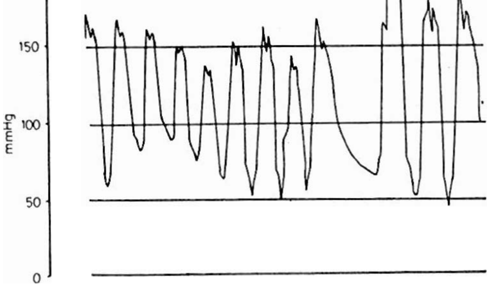
Patients should avoid exertion and not eat or smoke for thirty minutes before having their blood pressure measured. The room should be comfortably warm and quiet, and the patient should be allowed to rest for at least five minutes before the measurement. When it is not possible to achieve optimum conditions this should be noted with the blood pressure reading—for example, "BP 150/95/90 (patient very nervous)."

Obesity



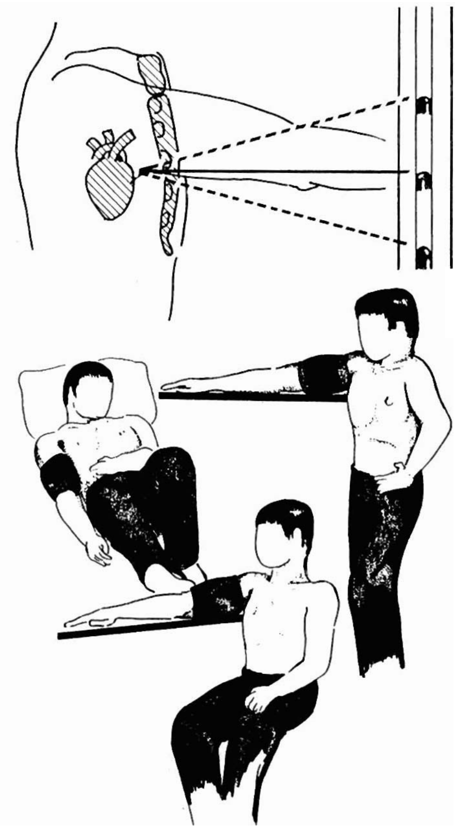
High blood pressure is commoner in obese people, but this increase may be at least partly artefactual, since the inflatable rubber bladder may be too short for the obese arm—causing "cuff hypertension." Ideally the bladder should encircle the arm, the recommended dimensions being 12×35 cm, but if the bladder does not do so (and most bladders will not) it should be 1·2 times wider than the arm's diameter (or 40% of arm circumference). When the bladder does not completely encircle the arm the centre of the bladder must be placed directly over the brachial artery.

Arrhythmias



Many cardiac arrhythmias cause variations in stroke volume, and the blood pressure may vary with each cardiac contraction. This is particularly so with atrial fibrillation. The average of at least three readings should be recorded for both systolic and diastolic pressure, and a note of the arrhythmia should be made with the blood-pressure reading. The mercury should be lowered very slowly to avoid underestimating systolic and overestimating diastolic pressures.

Arm position and support

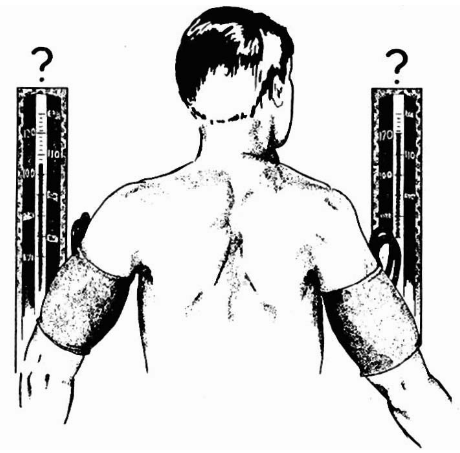


In normal people there is no significant difference in blood pressure between supine, sitting, and standing positions provided that the arm is supported at heart level. Patients should be comfortable whatever their position, and they should not change their position for five minutes before the blood pressure is measured. Some antihypertensive drugs cause postural hypertension, and when this is expected blood pressure should be measured both lying and standing.

Vertical displacement of the arm increases the hydrostatic pressure as the arm is lowered. The error may be as large as 10 mm Hg for both the systolic and diastolic pressures. The arm in which pressure is being measured should be horizontal with the fourth intercostal space at the sternum. This is especially important in the sitting and standing positions: in the supine position the arm is usually at heart level.

If the arm is unsupported the patient will perform isometric exercise, which may increase diastolic pressure by up to 10%. This effect is greater in hypertensive patients and in those taking beta-adrenoceptor blocking drugs. This isometric effect is most likely to occur in sitting and standing positions, when the arm has been extended forward at an angle of 45° to keep it at heart level. When extended this way the arm can readily be supported by the observer's arm.

Which arm?



There may be small differences in pressure between arms, and it has been suggested that pressures are higher in the right arm (by 2 to 10 mm Hg). In clinical practice most pressures are recorded from the right side.

At the initial examination, however, the blood pressure should be estimated in both arms. If the systolic or diastolic pressures are 10 mm Hg or more higher in one arm further measurements should be made in that limb.

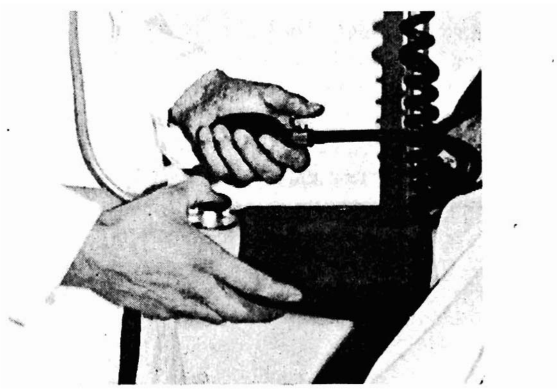
Repeated measurements

1. Inflate fast to 30 mmHg above systolic
2. Deflate at 2 mmHg/s
3. Note : appearance of sounds (systolic)
   muffling of sounds
   disappearance of sounds (diastolic)
4. Deflate rapidly to zero
5. Wait ≥15 s before repeating measurement

Repeated inflation of the bladder causes venous congestion of the limb, the duration of inflation rather than the pressure being the important factor. Systolic pressure may be up to 30 mm Hg above or 14 mm Hg below the true arterial level, and diastolic readings may be up to 20 mm Hg above or 10 mm Hg below the true level. To avoid venous congestion the cuff should be inflated as rapidly as possible and then deflated completely between successive readings. At least 15 seconds should be allowed between successive measurements.

TECHNIQUE

EOIN T O'BRIEN KEVIN O'MALLEY



Indirect blood pressure measurement by auscultation is susceptible to several errors, which may originate with the observer, the sphygmomanometer, the patient, or a combination of these factors.

By careful attention to detail blood pressure measurement with a sphygmomanometer can give systolic and diastolic pressures within 4 mm Hg of intra-arterial pressures.

Korotkoff sounds

Shortly after Scipione Riva-Rocci had invented the sphygmomanometer a Russian surgeon, Dr N C Korotkoff (left), reported that by placing a stethoscope over the brachial artery at the antecubital fossa distal to the Riva-Rocci cuff sounds could be heard. He documented the phases, and thus introduced the indirect auscultatory method of recording blood pressure.

Although the origin of the Korotkoff sounds is still not clear, vibratory and flow phenomena are probably responsible.

The phases are:

Phase 1—The first appearance of faint clear tapping sounds which gradually increase in intensity. The systolic pressure is heard for at least two consecutive beats, and this correlates well with intra-arterial pressure.

Phase 2—The softening of sounds, which may become swishing.

Phase 3—The return of sharper sounds, which become crisper but never fully regain the intensity of phase 1 sounds. Neither phase 2 nor phase 3 has any known clinical importance.

Phase 4—The distinct abrupt muffling of sounds, which become soft and blowing.

Phase 5—The point at which all sounds disappear completely.

Diastolic dilemma

Recommendations

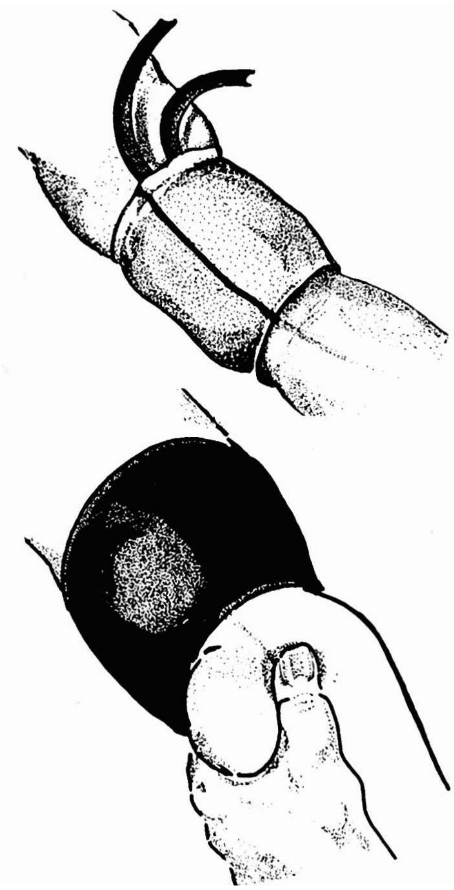
		Phase
1939	Cardiac Society of GB and Ireland and American Heart Association (AHA)	4
1951	AHA	5
1959	Build and Blood Pressure Study	5
1962	WHO	4&5
1967	AHA	4
1970	Veterans Administration Study	5
1972	Hypertension Detection and Follow-up Study	5
1974	Framingham Study	4
1975	Medical Research Council	5

Recommendations on blood pressure measurement have vacilated for many years on the issue of the diastolic endpoint. In the USA doctors have tended to favour the silent endpoint (phase 5), whereas in Britain and Ireland they have favoured the muffled endpoint (phase 4). In 1962 the World Health Organisation recommended that both phases 4 and 5 should be recorded. Inability to decide on an empirical matter of such importance is a source of inaccuracy and confusion.

Muffling and the disappearance of sounds may be synchronous, but usually there is a difference of 5 to 10 mm Hg. Phase 5 correlated best with intra-arterial pressure, but general acceptance of the silent endpoint has been resisted because patients in whom flow within the arterial circulation is increased—for example, after exercise and in other high-output states—may have a silent endpoint greatly below the muffling of sounds. In some patients sounds may be audible when cuff pressure is deflated even to zero. On the other hand, some patients do not have a distinct muffled endpoint.

There is greater agreement between observers using the silent rather than the muffled endpoint—a matter of importance in training observers, be they patients, nurses, or doctors. We recommend that the silent endpoint (phase 5) should be taken as the diastolic pressure. To avoid confusion, however, we support the suggestion that the fourth and fifth phases should always be noted—for example, 160/95/65 mm Hg, or when only the fourth or fifth phase has been recorded 160/95/- mm Hg or 160/-/65 mm Hg respectively.

Technique



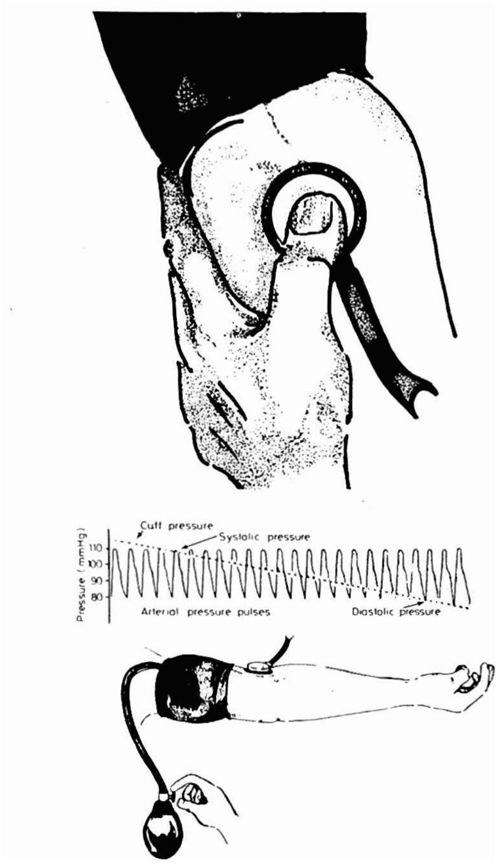
Firstly, the factors already discussed in relation to the observer, the instrument, and the patient should be taken into account.

Secondly, all clothing should be removed from the arm. If a blouse, shirt, or pyjama jacket is not to be removed it is better to leave the cloth under the cuff than roll the sleeve into a constricting band. If the cuff is not applied snugly to the arm falsely high blood pressures will be recorded, and if the cuff is too tight errors will also occur.

Thirdly, the cuff should be wrapped round the arm ensuring that the bladder dimensions are accurate. If the bladder does not completely encircle 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 we suggest that they should be placed superiorly or, with completely encircling bladders, posteriorly, so that the antecubital fossa is easily accessible for auscultation.

Fourthly, the brachial artery should be palpated with one hand, and the cuff 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 1 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 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.)

Technique



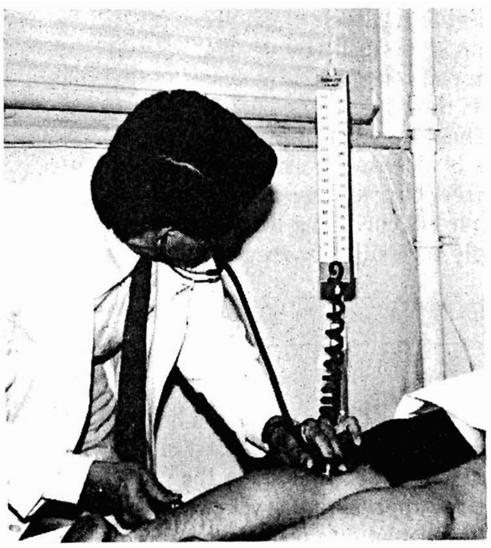
Fifthly, the stethoscope should be placed over the brachial artery. A bell endpiece gives better sound reproduction, but a diaphragm is easier to secure with the fingers of one hand and covers a larger area. The stethoscope should be held firmly and evenly but without excessive pressure. Too much pressure may distort the artery, producing sounds below diastolic pressure. To avoid friction sounds the stethoscope endpiece should not touch the clothing, cuff, or rubber tubes.

Sixthly, the cuff should be inflated as fast as possible to about 30 mm Hg above the palpated systolic pressure and deflated at a rate of 2 to 3 mm Hg per heart beat (or per second).

Seventhly, the appearance of sounds (phase 1) should be recorded as the systolic pressure, and the disappearance of sounds (phase 5) as the diastolic. Ideally both phases should be recorded but this is especially important if the difference between phases is over 10 mm Hg.

Finally, pressures should be recorded to the nearest 2 mm Hg. When all sounds have disappeared the cuff should be deflated rapidly and completely before repeating the measurement to prevent venous congestion of the arm.

Repeated measurements



If the blood pressure is raised on first measurement the recording should be repeated at least twice in the same arm. In patients with suspected coarctation of the aorta the blood pressure should be measured in the leg. A thigh cuff containing a large bladder (18×40 cm for adults) should be wrapped round the thigh of the prone patient and the Korotkoff sounds auscultated in the popliteal fossa in the usual way. The pressure in the legs is normally equal to that in the arms if the bladder is adequate in size.

At an initial examination blood pressure should be measured in both arms. If the difference between arms is more than 10 mm Hg for either systolic or diastolic pressure the arm with the higher pressure should be used for future measurements.

Except when the initial measurement is very high, indicating urgent treatment, the blood pressure should be measured on at least two separate occasions before starting treatment because as many as half the patients with raised blood pressures on initial examination will become normotensive on subsequent examination, and both systolic and diastolic pressures will be overestimated if based on a single casual estimation rather than repeated examination.

Ideally, therefore, records of blood pressure measurement should show the systolic pressure, the diastolic pressure, the endpoint used, the limb used and whether right or left, the position of the patient, and the presence of any arrhythmias or unusual circumstances such as anxiety or confinement to bed.

We thank Dr H Segall for the photograph of Korotkoff.

INFANCY AND CHILDHOOD

EOIN T O'BRIEN KEVIN O'MALLEY

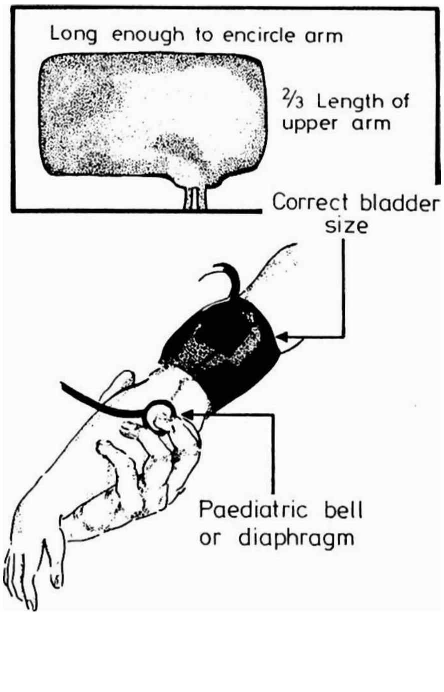
As in the adult, blood pressure measurement in children should be an indispensible part of clinical assessment—since doctors are becoming increasingly aware that hypertension may occur in childhood. If blood pressure readings in children are to be of value, however, the examiner must devote considerable care and time to his technique of measurement.

The physical stimuli affecting blood pressure—anxiety, fear, apprehension, agitation, activity, respiration, and temperature—are likely to be greater in children than in adults. Again, the observer may also have to allow for the effect of crying and restraint. The child must be relaxed, and in small children it may be helpful to give them a rubber teat to suck, even though sucking may itself raise the blood pressure.

It is important, particularly in infants and toddlers, to measure the blood pressure in the arms and legs. The systolic pressure in the leg is often said to be higher than in the arm, diastolic pressure being about the same, but any differences are probably due to inadequate cuff size.

There are five main methods of measuring blood pressure in children—auscultation, the flush method, visual oscillometry, palpation, and ultrasound. Impedance plethysmography has also been used, but clinical experience with the technique is limited. The auscultatory method is the commonest, but the Korotkoff sounds are softer in infants and children, so that accurate interpretation may be difficult and other techniques may be necessary.

Auscultation



The general recommendations on blood pressure measurement in the adult also apply to the child but a few points need emphasis.

Bladder size—Because of the variation in the size of the arm in children choosing a cuff containing the correct bladder size is important. A bladder that is too narrow or too short will give an erroneously high pressure. One that is too wide or too long will have the opposite effect. An index for making a choice of the proper cuff is available but is rarely used. The bladder width should cover about two-thirds of the length of the upper arm, and it should be long enough to encircle the arm completely. The length of the bladder is more important than width and if the optimal cuff is not available it is better to err with too large rather than too small a bladder. In hospital paediatric practice, where different observers may make serial observations, it is important to indicate bladder size with the blood pressure recording.

Stethoscope—The stethoscope used for auscultation should have a paediatric bell or diaphragm.

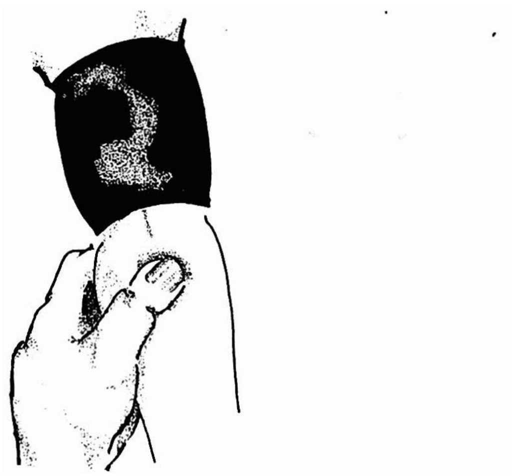
Diastolic end-point—As with the adult, there is controversy whether muffling (phase 4) or disappearance (phase 5) of the Korotkoff sounds is the better index of diastolic pressure. Even so, the muffled rather than the silent end-point is generally recommended.

The flush method

The flush method is based on the principle that if an extremity is drained of blood by compression it will blanch and the mean arterial pressure may be detected by observing the pressure at which the extremity flushes. Although clinically cumbersome, the method is useful.

A cuff containing a 5-cm wide inflatable bladder is applied to the wrist or ankle of the recumbent infant. The extremity distal to the cuff is raised and compressed by firmly wrapping it with an elastic bandage or soft rubber drain. (Holding it in the observer's hand is not sufficient because the extremity does not drain adequately.) When compression is complete, the cuff is inflated to 200 mm Hg, the wrapping removed, and cuff pressure slowly released at a rate not exceeding 5 mm Hg per second. The *mean* arterial pressure is the point at which the blanched distal portion of the hand or foot flushes. The technique is not accurate if there is severe anaemia, oedema, or hypothermia. Flush pressure tends to be a little higher in the wrist than in the ankle in the first year of life. The method may be particularly useful in diagnosing coarctation of the aorta.

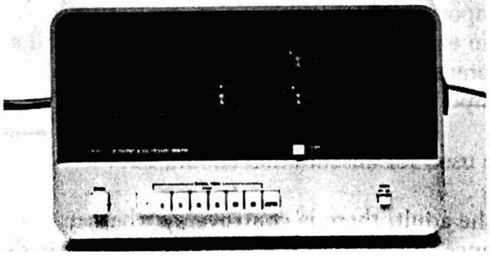
Palpation and visual oscillometry



Palpation in small children and infants of the arterial pressure distal to an occluding cuff may be the only means of obtaining an estimate of blood pressure. The systolic pressure is the point of appearance of the pulse as the pressure in the bladder is reduced. The blood pressure measured by palpation is usually 5-10 mm Hg lower than that measured by auscultation.

Visual oscillometry was popular at the turn of the century but is not much practised now. Sensitive electronic oscillometers, however, are now being developed and may become important in clinical practice. The oscillations of the arterial pulse are transmitted to a mercury column. The points at which oscillation appears and abruptly decreases as cuff pressure is lowered are taken as the systolic and diastolic pressures respectively. Maximal oscillation may represent mean arterial pressure.

Ultrasound



In small children and infants, in whom the Korotkoff sounds may be soft, methods of measuring blood pressure that depend on hearing the sounds are not satisfactory. Hence machines using ultrasound are becoming increasingly popular in paediatric hospital practice. The main drawback to using them more widely is their high cost.

The technique is based on the principle that an ultrasound wave directed towards an immobile structure such as an occluded artery will be reflected back without any change in frequency; a moving structure, such as the wall of a pulsating artery, will alter the reflected wave and will vary with the velocity of blood flow. The altered frequency of the reflected sounds may be amplified to produce a signal which can be detected by headphones or speakers and recorded or displayed.

The method is generally regarded as less accurate for diastolic than for systolic pressures. Even so, overall it is comparable with other indirect methods of measuring blood pressure in children.

The photograph of the Arteriosonde ultrasound machine was reproduced by kind permission of Kontron Medical and Laboratory Systems, St Albans.

FUTURE TRENDS

EOIN T O'BRIEN KEVIN O'MALLEY

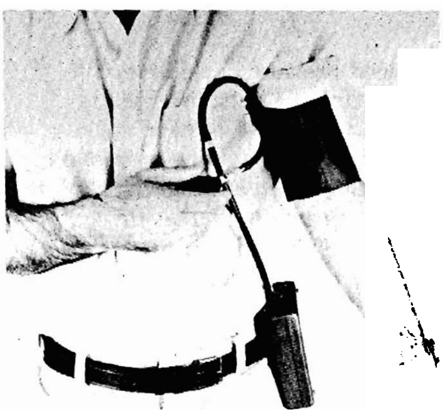
Semi-automated sphygmomanometers

The auscultatory method of measuring blood pressure is accurate enough for clinical practice if the observer is adequately trained and minimises error by attention to detail. Several semi-automated devices have recently appeared on the market claiming to be more accurate than conventional mercury or aneroid sphygmomanometers.

The basic assumption made by many manufacturers of these machines (and by some of the public who use them) is that automation will improve the accuracy of measurement. Nevertheless, many of these machines, which are much more expensive than a standard mercury manometer, are not as accurate. Most semi-automated devices incorporate some form of audiovisual signalling of end-points and some possess automatic control of inflation or deflation, or both. Some also provide a permanent record of the blood pressure, a facility which may reduce observer bias and error. Nevertheless, technical details on these machines are often lacking and the end-point selected for diastolic pressure may not be clearly defined.

Most semi-automated machines work on one of two principles—the detection of Korotkoff sounds (by human ear or a microphone) or the detection of arterial blood flow by ultrasound. Other techniques being developed include the phase-shift method, which measures pressure changes between two segments of a double cuff; infrasound recording; oscillographic detection of arterial pulsations with double arm cuff; tonometry, which depends on the principle that displacement of a force-sensitive transducer over a superficial artery can be made linearly proportional to the arterial blood pressure; and a technique that measures average pressures from a cuff at constant pressure.

Korotkoff-sound sphygmomanometers



A number of semi-automated devices based on Korotkoff-sound detection are available.

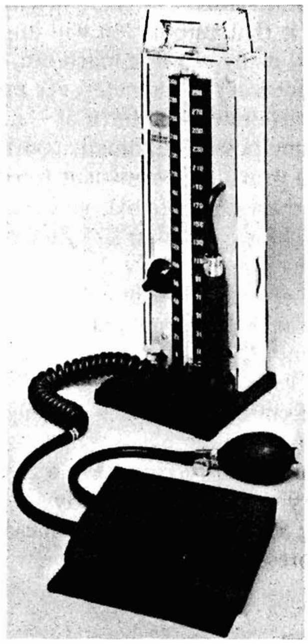
An electronic microphone shielded from extraneous noise in the pressure cuff will detect the Korotkoff sounds and indicate the pressure on a chart or audiovisually by bleeps or blinking lights. The microphones are sensitive to movement and friction, however, and are difficult to place accurately. Manual or automatic inflation and/or deflation may be available, and Korotkoff sounds can be recorded intermittently over 24 hours for ambulatory blood-pressure measurement. An example of an ambulatory recorder is the Remler machine.

Two semi-automated sphygmomanometers have been designed for clinical trials with the purpose of reducing observer bias and digit preference—the London School of Hygiene sphygmomanometer and the Hawkesley random-zero sphygmomanometer.

London School of Hygiene sphygmomanometer

The London School of Hygiene instrument has a standard cuff with automatic inflation and deflation at a constant rate. The cuff pressure registers on three mercury-in-glass columns, which are hidden from the operator. The operator auscultates the brachial artery pressure in the conventional way, stopping the descent of each column in turn by pressing buttons on the front of the instrument as Korotkoff phases 1, 4, and 5 are detected. A cursor in front of the mercury columns can be adjusted by a crankhandle to the meniscus of each column and the pressure is then displayed on a digital counter. Both observer bias and digit preference are thus eliminated. The instrument is too cumbersome for routine use, but it is accurate when assessed against direct intra-arterial measurements.

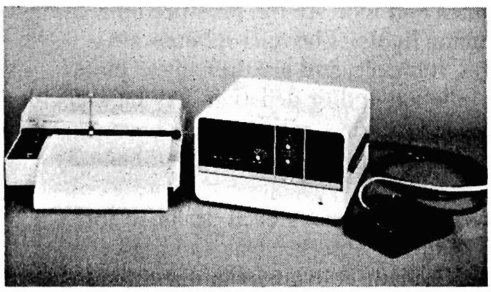
The Hawkesley random-zero sphygmomanometer



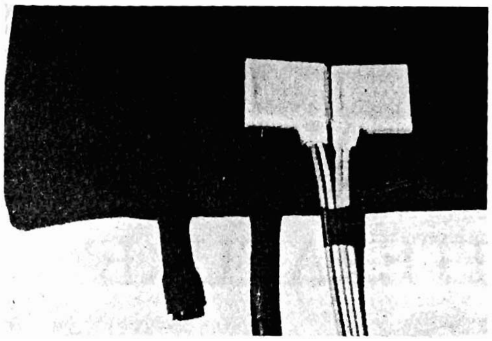
The random-zero manometer is only slightly larger than the conventional sphygmomanometer and operates in the same way, except that a wheel is spun before each measurement to adjust the zero to an unknown level. Once the blood pressure has been measured the level of zero may be determined and the pressure reading corrected.

In this way observer bias is reduced but not digit preference. The machine compares favourably with the standard mercury manometer and direct intra-arterial pressure.

Ultrasound sphygmomanometers

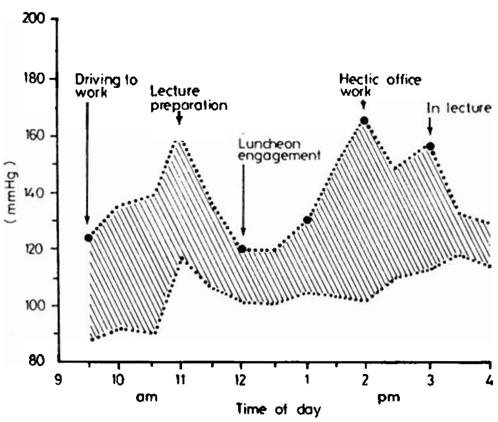


Ultrasound is valuable in measuring blood pressure in children, but ultrasound sphygmomanometers are also useful in adults, particularly those with low output states, such as shock, when the Korotkoff sounds may be difficult to detect. A small transmitting and receiving ultrasound transducer is incorporated in an inflatable cuff, which is wrapped round the arm in the conventional manner so that the transducer overlies the brachial artery. When the cuff is inflated above systolic pressure the artery is occluded and the transmitted ultrasound waves are reflected back without any change in frequency. As the cuff is deflated the vessel opens and closes, producing frequency changes in the reflected ultrasound waves, until the movement of the arterial wall ceases at pressures equal to and lower than diastolic pressure, when the reflected ultrasound will again have a constant frequency. The variations in frequency of reflected ultrasound may be amplified to produce a signal that can be detected by headphones or speakers and recorded or visualised.



Although ultrasound is not influenced by environmental noise, the transmitting and receiving crystals must be accurately fixed and stable over the brachial artery. Even minor shifts in position will produce considerable inaccuracies. Ultrasound sphygmomanometers have proved reasonably reliable and accurate when assessed against standard sphygmomanometers and direct intra-arterial measurements. Even so, their very high cost restricts their use to research projects and intensive care. For normal clinical use conventional sphygmomanometry is simpler, much cheaper, and every bit as accurate.

Continuous blood-pressure recording



Recordings of blood pressure over prolonged periods in ambulatory hypertensive patients and normal subjects have shown striking variations in the individual blood-pressure response to everyday stresses and activity. They have served to emphasise that the casual blood-pressure measurement, representing only 1/1400 of the total day's blood pressure, may be not only unrepresentative but frankly misleading, particularly in patients with borderline or labile hypertension. Unfortunately, methods for continuous ambulatory blood-pressure measurement are invasive and there have been serious complications. Most clinicians would be reluctant to leave an indwelling arterial catheter in situ while the patient performs normal activities outside hospital; hence this technique must be reserved for those few cases with special indications. There is no satisfactory method of continuously recording blood pressure non-invasively in an ambulant patient. Although a device has been designed to record pressures at pre-set intervals, the necessity for cuff inflation makes the subject aware of measurements.

Home recording of blood pressure

Name [redacted]

Drugs PRESSUREX DIUREX

Date	Blood pressure am S	Blood pressure am D	Blood pressure pm S	Blood pressure pm D	Dose am	Dose pm
1.9.79	174	104	210	112	80 2.5	80
2.9.79	200	108	212	110	80 2.5	80
3.9.79	198	104	222	116	80 2.5	80
4.9.79	202	100	206	105	80 2.5	80
5.9.79	186	98	198	100	80 2.5	80
6.9.79	176	94	180	98	80 2.5	80
7.9.79	180	90	180	94	80 2.5	80
8.9.79	190	98	204	104	100 2.5	100
9.9.79	164	92	190	106	100 2.5	100

The casual blood pressure may be unrepresentative of the patient's true blood pressure. Since there is no satisfactory technique for ambulatory measurement of blood pressure, doctors may try to obtain a more representative profile of blood-pressure behaviour by encouraging patients to record their own blood pressures. The patient, or his relative or friend, needs to be adequately trained in the technique. Even so, we believe that home recording of blood pressure is a useful means of obtaining information on the pattern of blood-pressure behaviour in selected patients. The patient should use a relatively cheap mercury or aneroid sphygmomanometer and stethoscope rather than one of the expensive and often inaccurate semi-automatic devices. His technique should be reviewed occasionally.

The photograph of the public blood-pressure machine was reproduced by kind permission of the *Irish Times*, that of the Remler machine by permission of Alphamed, that of the LSH machine by Professor G A Rose, that of the Hawkesley machine by Gelman Hawkesley Ltd, and that of the Arteriosonde ultrasound machine by Kontron.

RECONCILING THE CONTROVERSIES: A COMMENT ON THE "LITERATURE"

EOIN T O'BRIEN KEVIN O'MALLEY

In the 80 years since the sphygmomanometer was first introduced a large body of reports has developed around the subject. We comment here on some of the papers most relevant to our discussion on blood pressure measurement.

Aspects of measuring blood pressure

Observer error and the importance of training—The three major causes of observer error are: poor technique, observer bias, and terminal digit preference.[1] Proper training would probably do much to eliminate the errors arising from technique and bias,[2] but unfortunately the training techniques available are not widely known, and there is no standard programme for training and assessing competence.

The standard sphygmomanometer—Reports on the conventional sphygmomanometer show that as many as half the sphygmomanometers in hospital use are inaccurate[3] and that hospitals usually have no policy for maintaining sphygmomanometers. The mercury sphygmomanometer is the most accurate, reliable, durable, and economical of all sphygmomanometers and must be recommended for general use in preference to anaeroid and semi-automated devices. Several workers have examined the faults and problems common to sphygmomanometers.[3–8]

Cuff bladder dimensions—Selecting the best dimensions for the inflatable rubber bladder is one of the most controversial topics in blood pressure measurement. The best width for the bladder is generally agreed to be 12 to 14 cm, and it would seem reasonable to choose a 12-cm wide cuff for adults to allow as much room as possible for applying the stethoscope. Three independent groups of workers[9–11] have shown that the most accurate blood pressure measurements were obtained when the bladder completely encircled the arm and they recommended a bladder length of 40 cm. More recently, Burch and Shewey[12] challenged this recommendation, showing that a bladder encircling half the arm circumference was adequate, and pleaded for retaining the standard 23-cm long bladder. There the controversy rests for the moment, and the most reasonable compromise would be to recommend a 35-cm long bladder that would encircle most adult arms.[3] We recommend that the bladder should measure 12×35 cm and if a bladder smaller than this is used the centre of the bladder must be placed over the brachial artery.

Factors affecting the patient—Environmental factors and the patient's general physiological state are major influences on blood pressure measurement.[13] Perhaps less well known is the relevance of obesity,[14] arrhythmias,[5] the arm chosen,[15] the level of the arm,[16] isometric exercise in the unsupported arm,[17] and venous congestion of the limb due to repeated measurements.

The diastolic dilemma—The choice of Korotkoff phase 4 (muffling of sounds) or phase 5 (disappearance of sounds) as the true diastolic pressure has been a major controversy and source of confusion in several reviews on the technique of blood pressure measurement.[2,5,6,19,20] The matter is more tl an academic quibble: the difference between phases n average as much as 10 mm Hg.[21] General opinion now favo the fifth phase, because it is closer to the intra-arterial diast(pressure and there is better agreement between observers determining disappearance of sounds. Occasionally, howe\ the sounds disappear at a pressure considerably below that muffling, and we support the recommendation of the exp committee of the World Health Organisation[22] to record b phases.

Infancy and childhood—The principles of blood press measurement are the same for all ages, but in small child: and infants it takes more time to obtain an accurate measu ment. Selection of the appropriate cuff size is important,[23] ε although phase 4 (muffling) is generally recommended for diastolic pressure, the best practice would be to record b phases.

New devices—The number of reports on new developme in techniques for measuring blood pressure[1,4,8,24–28] is s prisingly small, and the reports are often lacking in det possibly reflecting the gap between medical and engineer interests. Indeed it is surprising that there has been so li development in techniques of measurement. None of the ne\ devices, no matter how advanced or costly, appear to be bet than the simple (and cheap) conventional mercury sphygn manometers; it is worrying that blood pressure measur devices can be sold to the public (and medical profession) the basis of claims that have not been adequately assessed. A f independent surveys of semi-automated devices have sho that the standard of engineering and quality control is of poor; and many of these devices are very expensive: gadge may raise the cost of a standard mercury sphygmomanome above £100 without increasing its accuracy; ultrasound machi generally cost over £2000, and equipment for ambulat(recording is very expensive. The random-zero sphygmoman meter[27] is an accurate instrument that eliminates a ma source of error—namely, observer bias—and the princi might be developed further and incorporated in many standa sphygmomanometers.

Ambulatory recording—Two of the most important decisi(for the hypertensive patient are the reaching of a diagnosis, a starting treatment. Neither decision should be made (except extreme cases) on the basis of casual readings. The folly relying on casual surgery or hospital blood pressure readi in artificial circumstances has been clearly shown,[28] and it well recognised that blood pressure falls between success visits. The striking variation in blood pressure during norr daily activity has been clearly shown by continuous recordi of blood pressure,[8,28] and many studies have confirmed that t average ambulatory blood pressure is generally lower than t average values shown by casual measurements. Furthermo there is some evidence that the cardiovascular complicati(of hypertension are more closely related to mean pressure o\ 24 hours than to casual readings.[28] Unfortunately, techniq\

for continuous blood pressure measurement are invasive, and although they provide much-needed information on blood pressure behaviour they are not applicable in routine practice. (Direct intra-arterial measurement is, of course, very valuable in patients with obesity or in those in whom the blood pressure is difficult to measure with a conventional sphygmomanometer.) Non-invasive techniques for recording ambulatory blood pressure depend on cuff occlusion and therefore record intermittent rather than continuous pressure.[28, 29] Clinical experience with the few devices available is limited, mainly because they are very expensive, but development of a cheap and accurate means of ambulatory recording would have a considerable impact on the diagnosis of borderline hypertension and the assessment of the efficacy of treatment.

Home recording—We have found home recording of blood pressure by the patient, a relative, or a friend to be practicable and a useful guide to management, and see the technique serving as a compromise between casual and continuous recording. Home recording has never been popular, probably because guidelines for training subjects have not been stated adequately, but several workers have found the practice valuable.[29]

Conclusion

In this series we have examined the many sources of error in blood pressure measurement and suggested ways of improving technique. In particular, we have emphasised the importance of training, eliminating observer bias, using a bladder of adequate size, maintaining equipment, and accepting 5th-phase diastolic pressure. The mercury sphygmomanometer is the most accurate device for indirect measurement of blood pressure, and newer, more expensive, and often less accurate pieces of equipment should be viewed critically unless they have been independently assessed by a reputable laboratory. Ambulatory recording is important but the lack of cheap non-invasive techniques makes home-recording the most satisfactory means of obtaining a profile of blood pressure response to daily activities.

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