



## ABC of hypertension: Blood pressure measurement

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*ABC of hypertension***Blood pressure measurement***Part II—Conventional sphygmomanometry: technique of auscultatory blood pressure measurement*

Gareth Beevers, Gregory Y H Lip, Eoin O'Brien

The measurement of blood pressure in clinical practice by the century-old technique of Riva-Rocci/Korotkoff is dependent on the accurate transmission and interpretation of a signal (Korotkoff sound or pulse wave) from a subject via a device (the sphygmomanometer) to an observer. Errors in measurement can occur at each of these interactionary points of the technique, but by far the most fallible component is the observer.

*This article has been adapted from the newly published 4th edition of ABC of Hypertension. The book is available from the BMJ bookshop and at [www.bmjbooks.com](http://www.bmjbooks.com)*

**Observer error**

In 1964, Geoffrey Rose and his colleagues classified observer error into three categories.<sup>1</sup>

**Systematic error**

This leads to both intraobserver and interobserver error. It may be caused by lack of concentration, poor hearing, confusion of auditory and visual cues, etc. The most important factor is failure to interpret the Korotkoff sounds accurately, especially for diastolic pressure.

**Terminal digit preference**

This refers to the phenomenon whereby the observer rounds off the pressure reading to a digit of his or her choosing, most often to zero. Doctors may have a 12-fold bias in favour of the terminal digit zero; this has grave implications for decisions on diagnosis and treatment, although its greatest effect is in epidemiological and research studies in which it can distort the frequency distribution curve and reduce the power of statistical tests.<sup>2</sup>

**Observer prejudice or bias**

This is the practice whereby the observer simply adjusts the pressure to meet his or her preconceived notion of what the pressure should be. It usually occurs when there has been recording of an excess of pressures below the cut-off point for hypertension and it reflects the observer's reluctance to diagnose hypertension. This is most likely to occur when an arbitrary division is applied between normal and high blood pressure, for example 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 overreading blood pressure to facilitate recruitment for a research project, such as a drug trial. Observer prejudice is a serious source of inaccuracy, as the error cannot usually be demonstrated.<sup>3</sup>

**Overcoming error by observer training**

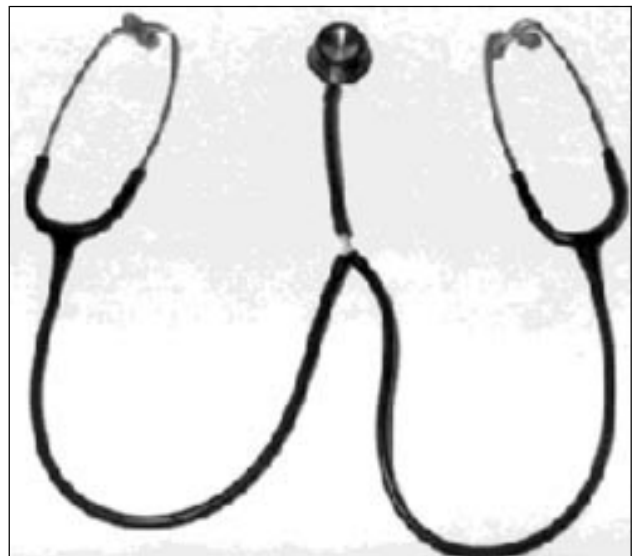
The technique of auscultatory blood pressure measurement is a complicated one that is often taken for granted. Instruction to medical students and nurses has not always been as comprehensive as it might be, and assessment for competence in measuring blood pressure has been a relatively recent development.<sup>4</sup> Ironically, these methods of achieving much needed improvement in performing the auscultatory technique have arrived as the mercury sphygmomanometer is under threat and as automated devices move in to replace the observer; these have included: direct instruction using a

**Rose classification of observer error**

- Systematic error
- Terminal digit preference
- Observer prejudice

**Observer training techniques**

- Direct instruction by an experienced observer
- Instruction manuals and booklets
- Audiotapes
- Video films
- CD Rom presentations



Binaural stethoscope used for instruction in auscultatory blood pressure measurement

binaural stethoscope; the use of manuals, booklets, and published recommendations; audiotape training methods; videofilm methods, and, most recently, CD Rom methods. The CD Rom produced by the Working Party on Blood Pressure Measurement of the British Hypertension Society in 1998<sup>5</sup> incorporates instruction, with examples of blood pressure measurement using a falling mercury column with Korotkoff sounds and a means for the student to assess competence in the technique using a series of examples. The CD is accompanied by the British Hypertension Society booklet *Blood pressure measurement: recommendations of the British Hypertension Society*.<sup>6</sup>

#### Overcoming error with instrumentation

As mentioned earlier, blood pressure measurement is subject to observer prejudice and terminal digit preference, introducing an error that is unacceptable for research work. Careful training of observers can reduce but not abolish these sources of error, some of which cannot be easily demonstrated. Because accuracy of measurement is particularly desirable in research, efforts have been made to devise devices that would minimise or abolish observer error.

## Measuring blood pressure

Assuming the observer has been trained and shown to be proficient in the technique there are then a number of factors that may affect the performance of the technique.<sup>5 6</sup> Some of these factors are described below.

#### Attitude of observer

Before taking the blood pressure, the observer should be in a comfortable and relaxed position, because if hurried the pressure will be released too rapidly, resulting in underestimation of systolic and overestimation of diastolic pressures. If any interruption occurs the exact measurement may be forgotten and an approximation made, so the blood pressure should always be written down as soon as it has been measured.

## Mercury and aneroid sphygmomanometers

The mercury sphygmomanometer is a reliable device, but all too often its continuing efficiency has been taken for granted, whereas the aneroid manometer, which is not generally as accurate, is often assumed to be as reliable. These devices have certain features in common; each has an inflation-deflation system, and occluding bladder encased in a cuff, and both devices measure blood pressure by auscultation using a stethoscope.

#### Inflation-deflation system

The inflation-deflation system consists of an inflating and deflating mechanism connected by rubber tubing to an occluding bladder. 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

### Recommendations for observer training

#### Training observers in clinical practice: nursing and medical students, doctors, paramedical personnel

- Instruction in the theory of hypertension and blood pressure measurement
- Booklet for reading, eg BHS *Recommendations on blood pressure measurement*
- Tutorial sessions with demonstrations using a binaural or multiaural stethoscope
- CD Rom demonstration using, eg, the BHS CD Rom
- CD Rom assessment
- Repeat CD Rom assessment until level of accuracy achieved
- Reassessment using BHS CD Rom every two years

#### Training observers in research

- Measurement of blood pressure—highest possible standard
- Level of accuracy—90% of SBP and DBP within 5 mm Hg—100% within 10 mm Hg of an expert observer
- Instruction in the theory of hypertension and blood pressure measurement
- Audiogram to check auditory acuity
- Booklet for reading, eg BHS *Recommendations on blood pressure measurement*
- Tutorial sessions with demonstrations using a binaural or multiaural stethoscope
- CD Rom demonstration using, eg the BHS CD Rom
- CD Rom assessment
- Repeat CD Rom assessment until level of accuracy achieved
- Training and assessment repeated at least every three months



Relaxed subject



Mercury sphygmomanometer

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

A very common source of error in sphygmomanometers is the control valve, especially when an air filter rather than a rubber valve is used. Defective valves cause leakage, making control of pressure release difficult; this leads to underestimation of systolic and overestimation of diastolic pressures. Faults in the control valve may be corrected easily by simply cleaning the filter or replacing the control valve. It is helpful to have a checklist of possible faults and the means of rectifying these.

#### Hazards of mercury

The mercury sphygmomanometer is a simple and accurate device, which can be easily serviced, but there are rightly concerns about the toxicity of mercury for individuals using mercury sphygmomanometers, and for those who have to service them. Users should be alert therefore to the hazards associated with handling mercury.<sup>7</sup>

However, the greatest concern about mercury is its toxic effects on the environment. The call to have mercury removed from hospitals comes from the environmental lobby, which, quite correctly, sees mercury as a toxic, persistent, and bioaccumable substance. What happens, they ask, to the many tons of mercury supplied for the manufacture of sphygmomanometers and then distributed throughout the world to hospitals and countless individual doctors? Quite simply it finds its way back into the environment through evaporation, sewage, or in solid waste, most seriously damaging the marine environment, and it accumulates in soil and in sediments thereby entering the food chain.

The mercury thermometer has been replaced in many countries, and in Sweden and the Netherlands the use of mercury is no longer permitted in hospitals. However, in other European countries, including the UK and Ireland, the move to ban mercury from hospital use has not been received with enthusiasm on the grounds that there is no accurate alternative device to the mercury sphygmomanometer. None the less, the fear of mercury toxicity is making it difficult to get mercury sphygmomanometers serviced, and the precautions recommended for dealing with a mercury spill are influencing purchasing decisions. Indeed, this is what central governmental policy in many countries would favour—the gradual disappearance of mercury from hospitals should a ban become operative.<sup>8-10</sup>

#### Preparing for the end of the mercury sphygmomanometer

Although it will be some years before any move is made to replace the millimetre of mercury, we must prepare for changes in clinical sphygmomanometry. Several simple measures can be instigated immediately. Healthcare providers are being encouraged to phase out mercury sphygmomanometers and replace them only with devices that have been independently validated against the relevant protocols. Automated devices should provide blood pressures in both millimetres of mercury and kilopascals, so that users can become familiar with kilopascals. Finally, the medical and nursing professions, which constitute the clinical market for blood pressure measuring devices, must ensure that manufacturers provide us with accurate devices designed to our specifications, rather than accepting, as we have done in the past, devices in which these considerations are secondary to the commercial success of the product.<sup>11</sup>

#### Aneroid manometers

Aneroid sphygmomanometers register pressure through a bellows and lever system, which is mechanically more intricate

#### Consequences of defects in the control valve

Pumping control valve	little or no effort required
<i>Excessive squeeze on the pump</i>	<i>filter blocked</i>
With valve closed	mercury at level steady
<i>Falling mercury</i>	<i>leak in inflation system</i>
With valve released	controlled fall of mercury
<i>Failure to control mercury fall</i>	<i>leak in inflation system</i>

#### Advice to be included in the instructions accompanying a sphygmomanometer using a mercury manometer (from European Standard EN 1060-2)

##### B1 Guidelines and precautions

A mercury-type sphygmomanometer should be handled with care. In particular, care should be taken to avoid dropping the instrument or treating it in any way that could result in damage to the manometer. Regular checks should be made to ensure that there are no leaks from the inflation system and to ensure that the manometer has not been damaged so as to cause a loss of mercury.

##### B2 Health and safety when handling mercury

Exposure to mercury can have serious toxicological effects; absorption of mercury results in neuropsychiatric disorders and, in extreme cases, nephrosis. Therefore precautions should be taken when carrying out any maintenance to a mercury-type sphygmomanometer.

When cleaning or repairing the instrument, it should be placed on a tray having a smooth, impervious surface which slopes away from the operator at about 10° to the horizontal, with a water filled trough at the rear. Suitable gloves (eg of latex) should be worn to avoid direct skin contact. Work should be carried out in a well ventilated area, and ingestion and inhalation of the vapour should be avoided.

For more extensive repairs, the instrument should be securely packed with adequate packing, sealed in a plastic bag or container, and returned to a specialist repairer. It is essential that a high standard of occupational hygiene is maintained in premises where mercury containing instruments are repaired. Chronic mercury absorption is known to have occurred in individuals repairing sphygmomanometers.

##### B3 Mercury spillage

When dealing with a mercury spillage, wear latex gloves. Avoid prolonged inhalation of mercury vapour. Do not use an open vacuum system to aid collection. Collect all the small droplets of spilt mercury into one globule and immediately transfer all the mercury into a container, which should then be sealed.

After removal of as much of the mercury as practicable, treat the contaminated surfaces with a wash composed of equal parts of calcium hydroxide and powdered sulfur mixed with water to form a thin paste. Apply this paste to all the contaminated surfaces and allow to dry. After 24 h, remove the paste and wash the surfaces with clean water. Allow to dry and ventilate the area.

##### B4 Cleaning the manometer tube

To obtain the best results from a mercury-type sphygmomanometer, the manometer tube should be cleaned at regular intervals (eg under the recommended maintenance schedule). This will ensure that the mercury can move up and down the tube freely, and respond quickly to changes in pressure in the cuff.

During cleaning, care should be taken to avoid the contamination of clothing. Any material contaminated with mercury should be sealed in a plastic bag before disposal in a refuse receptacle.

than the mercury reservoir and column. The jolts and bumps of everyday use affect their accuracy; they lose accuracy over time, usually leading to falsely low readings with the consequent underestimation of blood pressure. They are therefore less accurate in use than mercury sphygmomanometers. When calibrated against a mercury sphygmomanometer a mean difference of 3 mm Hg is considered to be acceptable; however, 58% of aneroid sphygmomanometers have been shown to have errors greater than 4 mm Hg, with about one third of these having errors higher than 7 mm Hg.<sup>12</sup> Moreover, aneroid sphygmomanometry is prone to all the problems of the auscultatory technique, namely observer bias and terminal digit preference.

## Position of manometer

The observer should take care when positioning the manometer:

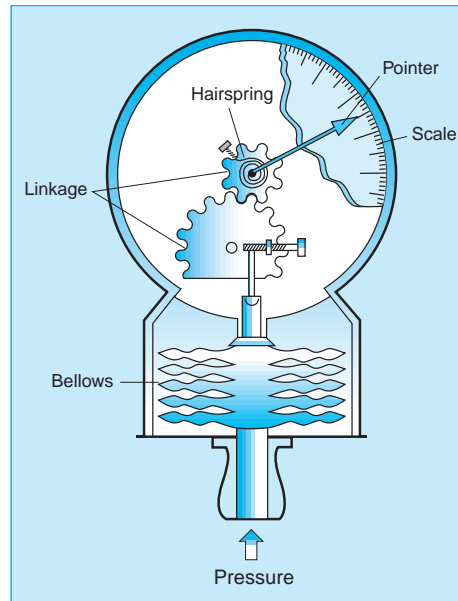
- The manometer should be no further than three feet (92 cm) away so that the scale can be read easily.
- The mercury column should be vertical (some models are designed with a tilt) and at eye level—this is achieved most effectively with stand mounted models, which can be easily adjusted to suit the height of the observer.
- 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.

## Placing the cuff

The cuff should be wrapped around the arm ensuring that the bladder dimensions are accurate. If the bladder does not completely encircle the arm its centre 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.

## Palpatory estimation of blood pressure

The brachial artery should be palpated while the cuff is rapidly inflated to about 30 mm Hg above the point where the pulse disappears; the cuff is then slowly deflated, and the observer notes the pressure at which the pulse reappears. This is the approximate level of the systolic pressure. Palpatory estimation is important because phase I sounds sometimes disappear as pressure is reduced and reappear at a lower level (the auscultatory gap), resulting in systolic pressure being underestimated unless already determined by palpation. The palpatory technique is useful in patients in whom auscultatory endpoints 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.)



Mechanism of an aneroid sphygmomanometer



Correct placement of cuff and bladder



Palpating artery

## Auscultatory measurement of systolic and diastolic pressures

- Place the stethoscope 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 larger area.
- The stethoscope should be held firmly and evenly but without excessive pressure—too much pressure might distort the artery, producing sounds below diastolic pressure. The stethoscope end-piece should not touch the clothing, cuff, or rubber tubes to avoid friction sounds.
- The cuff should then be inflated rapidly to about 30 mm Hg above the palpated systolic pressure and deflated at a rate of 2-3 mm Hg per pulse beat (or per second), during which the auscultatory phenomena 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 phases shown in the box, which were first described by Nicolai Korotkoff and later elaborated by Witold Ettinger, can be heard.<sup>13</sup>

### Diastolic dilemma

For many years recommendations on blood pressure measurement have been uncertain about the diastolic endpoint—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. There has been resistance to general acceptance of the silent endpoint until recently, because the silent endpoint can be greatly below the muffling of sounds in some groups of patients—children, pregnant women, anaemic or elderly patients. In some patients sounds may even be audible when cuff pressure is deflated to zero. There is now a general consensus that disappearance of sounds (phase V) should be taken as diastolic pressure except in those subjects mentioned above (as originally recommended by Korotkoff in 1910).<sup>13</sup>

### Recording blood pressure

The points to be noted when measuring blood pressure are listed in the box opposite.

### Number of measurements

One measurement should be taken carefully at each visit, with a repeat measurement if there is uncertainty or distraction; do not make a number of hurried measurements.

As a result of the variability of measurements of casual blood pressure, decisions based on single measurements will result in erroneous diagnosis and inappropriate management. Reliability of measurements is improved if repeated measurements are made. The alarm reaction to blood pressure measurement may persist after several visits, so for 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.

BMJ 2001;322:1043-7

### Auscultatory sounds

- *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
- *Auscultatory gap*—In some patients sounds may disappear altogether for a short time
- *Phase III*—The return of sharper sounds, which become crisper to regain, or even exceed, 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

### What to note when measuring 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 mm Hg
- Pressures should not be rounded off to the nearest 5 or 10 mm Hg—digit preference
- The arm in which the pressure is being recorded and the position of the subject should be noted
- Pressures should be recorded in both arms on first attendance
- In obese patients the bladder size should be indicated
- If a “standard cuff” containing a bladder with the dimensions 23 × 12 cm has to be used, it is best to state this together with the measurement so that the presence of “cuff hypertension” can be taken into account in diagnostic and management decisions and arrangements can be made for a more accurate measurement
- In clinical practice the diastolic pressure should be recorded as phase V, except in those patients in whom sounds persist greatly below muffling; this should be clearly indicated
- In hypertension research both phases IV and V should be recorded
- If the patient is anxious, restless, or distressed a note of this should be made with the blood pressure
- The presence of an auscultatory gap should always be indicated
- In patients taking blood pressure lowering drugs the optimal time for control of blood pressure will depend on the timing of the drugs; when assessing the effect of antihypertensive drugs the time of drug ingestion should be noted in relation to the time of measurement

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