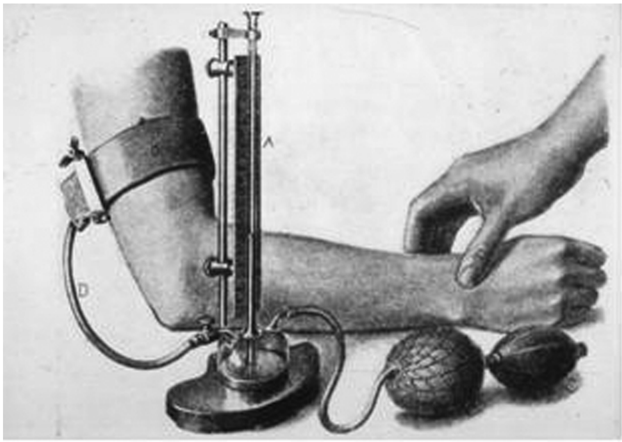
Part II Conventional sphygmomanometry

Basic requirements for auscultatory measurement of blood pressure

The century old technique of Riva Rocci/Korotkoff is now recognised to be fraught with inaccuracies that may lead to the misdiagnosis of abnormal blood pressure in many people. As a result, the auscultatory technique is being replaced by automated techniques, and its place in medicine may soon be of historical rather than practical interest. Measurement of blood pressure in clinical practice is dependent on the accurate transmission and interpretation of a signal (the Korotkoff sound or pulse wave) from a patient through a device (the sphygmomanometer) to an observer. Errors in measurement can occur at any interaction point during the technique, but the observer is by far the most fallible component.

Observer error

The major cause of observer error is the variability of blood pressure and the misleading measurements that constitute the phenomena of white coat hypertension and masked hypertension now may be added to this list. Training of observers in the technique of auscultatory measurement of blood pressure 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 the measurement of blood pressure has been a relatively recent development. A number of training methods exist.



Riva-Rocci sphygmomanometer. Reproduced from O'Brien E, Fitzgerald D. The history of indirect blood pressure measurement. In: *Blood pressure management* O'brien E, O'Malley K, eds. Amsterdam: Elsevier, 1991

Observer influences

- Systematic error—intraobserver and interobserver error
- Terminal digit preference—rounding off to favoured digit, usually 0
- Observer prejudice—choice of measured pressure influenced by what observer wishes it to be
- White coat hypertension—high office and normal daytime ambulatory blood pressure
- Masked hypertension—normal office and high daytime ambulatory blood pressure

Training methods

- Direct instruction with a binaural of multiaural stethoscope
- Manuals, booklets and guidelines
- Audiotapes, CD-Rom, and DVD with instruction and visual falling mercury column and Korotkoff sounds permitting assessment of competence

Mercury and aneroid sphygmomanometers

The mercury sphygmomanometer is a reliable device, but all too often its continuing efficiency has been taken for granted. Aneroid manometers are not as accurate. These two types of device have certain features in common; these are:

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 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 to the sphygmomanometer. One of the most common sources of error in sphygmomanometers is the control valve.

Mercury sphygmomanometers

The mercury sphygmomanometer is a simple and accurate device that can be serviced easily, but concerns rightly exist about the toxicity of mercury for people who use mercury sphygmomanometers and those who service them. The greatest concern about mercury, however, is its toxic effect on the environment, and mercury increasingly is being banned from use in medicine.

Aneroid sphygmomanometers

Aneroid sphygmomanometers register pressure through a bellows and lever system that is more intricate mechanically than the mercury reservoir and column. The jolts and bumps of

Mercury sphygmomanometer

Features and weaknesses common to mercury and aneroid sphygmomanometers

Features
- Inflation-deflation system
- Occluding bladder encased in a cuff
- Auscultation of Korotkoff sounds with stethoscope
- Connecting rubber tubing

Weaknesses
- Defective control valve—leakage:
  - —Underestimation of systolic blood pressure
  - —Overestimation of diastolic blood pressure
- Leaks as a result of cracked or perished rubber:
  - —Mercury fall cannot be controlled
- Inadequate tubing:
  - —Minimum length of 70 cm between cuff and manometer
  - —Minimum length of 30 cm between pump and cuff
- Connections not airtight

everyday use affect accuracy over time, which usually leads to falsely low readings and thus underestimations of blood pressure. They are therefore less accurate in use than mercury sphygmomanometers. Moreover, aneroid sphygmomanometry is also prone to all the problems of the auscultatory technique. As mercury sphygmomanometers are removed from clinical practice, people tend to replace them with aneroid devices on the false assumption that they are equally accurate. Remarkably little literature exists on the accuracy of aneroid devices and what does is generally negative (see www.dableducational.org).

Stethoscope
A stethoscope should be of high quality, with clean and well fitting earpieces. Whether the bell or diaphragm is used in routine measurement of blood pressure probably does not matter much, as long as the stethoscope is placed over the palpated brachial artery in the antecubital fossa. As the diaphragm covers a larger area and is easier to hold than a bell endpiece, it is reasonable to recommend it for routine clinical measurement of blood pressure.

Maintenance
To check and maintain mercury sphygmomanometers is easy, but great care should be taken when mercury is handled. Mercury sphygmomanometers need cleaning and checking at least every six months in hospital use and every 12 months in general use. In practice, doctors often neglect to have sphygmomanometers checked and serviced. The responsibility for reporting faulty equipment or lack of appropriate cuffs lies with the observer, who should always refuse to use defective or inappropriate equipment.

Aneroid sphygmomanometers should be checked every six months against an accurate mercury sphygmomanometer over the entire pressure range. This can be done by connecting the aneroid sphygmomanometer via a Y piece to the tubing of the mercury sphygmomanometer and inflating the cuff around a bottle or cylinder. If inaccuracies or other faults are found, the instrument must be repaired by the manufacturer or supplier.

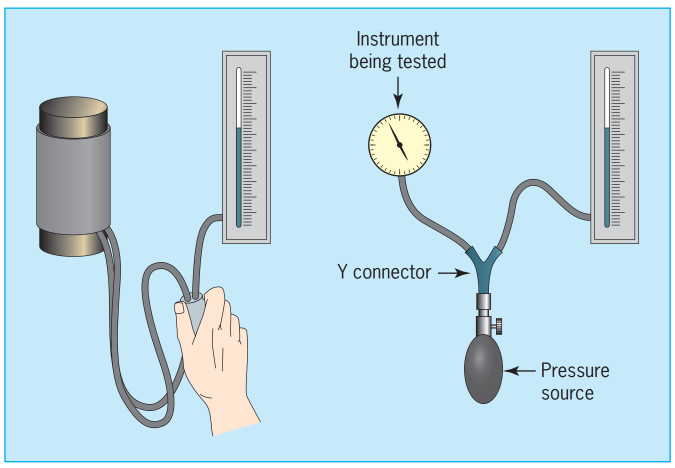
Alternative devices to mercury sphygmomanometers

Non-automated devices
Oscillometric measurement of blood pressure has a number of inherent limitations. It is therefore unlikely to be accepted as the gold standard for conventional measurement of blood pressure.

Aneroid gauge. With permission from Miriam Maslo/Science Photo Library

Placement of stethoscope With permission from Sheila Terry/Scienc e Photo Library

Accuracy limits
- Difference in accuracy of aneroid *v* mercury sphygmomanometer <3 mm Hg
- Surveys have shown:
  - —58% aneroid devices have errors >4 mm Hg
  - —30% aneroid devices have errors >7 mm Hg
  - —50% hospital sphygmomanometer are defective
- Maintenance policy is mandatory but rarely in place



Calibration of aneroid sphygmomanometer

Alternative devices to the mercury sphygmomanometer, which combine the features of electronic and mercury devices by using an electronic pressure gauge as a substitute for the mercury column, are now being produced. These devices, which are known as "hybrid" sphygmomanometers, display cuff pressure as a simulated mercury column with an array of liquid crystal displays and as a digital readout on a liquid crystal display. The cuff is deflated in the normal way; when systolic and diastolic pressure are heard, a button next to the deflation knob is pressed, which freezes the digital display to show systolic and diastolic pressures. This therefore offers the potential of eliminating terminal digit preference, which is a major problem with the clinical use of any auscultatory monitor. The observer is therefore able to measure blood pressure with the traditional auscultatory technique without necessarily having to rely on automated readings. This is achieved without the problems associated with mercury columns or aneroid devices.

Automated devices
As technology improves, mercury and aneroid devices will soon be replaced by accurate automated sphygmomanometers.

Mercury free sphygmomanometer

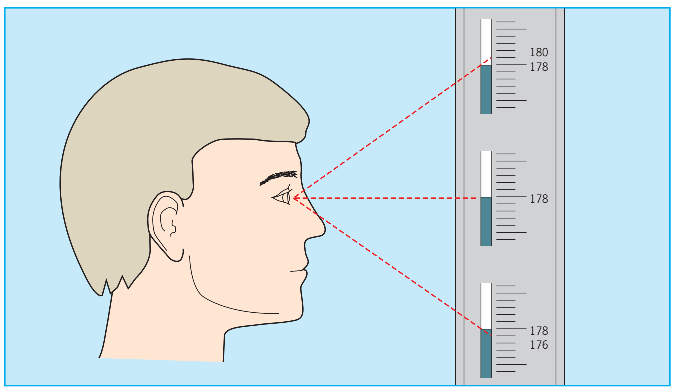
Advantages and disadvantages of automated devices

Advantages
- Provide printouts with:
  —Systolic and diastolic blood pressure
  —Mean blood pressure
  —Heart rate
  —Time of measurement
  —Date of measurement
- Eliminate observer error
- Eliminate observer bias
- Eliminate observer digit preference
- Minimal training needed
- Store data for future analysis and comparision
- Ability to plot trends

Disadvantages
- Poor record for accuracy but improving
- Designed for self measurement rather than clinical use
- All use oscillometric measurement
  —Point of maximal cuff oscillation—mean blood pressure
  —Systolic and diastolic blood pressure derived from algorithm
  —Details of algorithm known only to manufacturer
- Oscillometric technique fails in some individuals
- Oscillometric technique not accurate in rapid atrial fibrillation

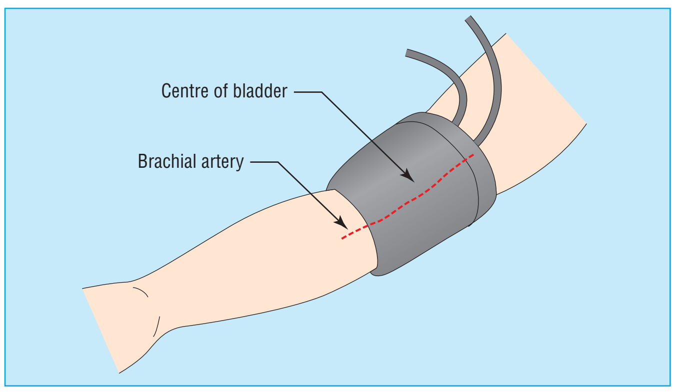
Performing auscultatory measurements

Position of manometer
The observer should take care to position the manometer so that the scale can be read easily. Accurate measurement is achieved most effectively with stand mounted models, which can easily be 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 it must be viewed straight on, with the eye on a line perpendicular to the centre of the face of the gauge.



Eye level

Placement of cuff
The cuff should be wrapped around the arm, ensuring that the dimensions of the bladder 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 placing them superiorly allows easy access to the antecubital fossa for auscultation. The lower edge of the cuff should be 2–3 cm above the point of brachial artery pulsation.



Placement of cuff

Palpatory estimation of blood pressure
The brachial artery should be palpated while the cuff is inflated rapidly to about 30 mm Hg above the point where the pulse disappears; the cuff is then deflated slowly, 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), which results 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, and those who are exercising. (The radial artery is often used for palpatory estimation of the systolic pressure but use of the brachial artery also allows the observer to establish its location before auscultation begins.)

Diastolic dilemma
For many years recommendations on blood pressure measurement have been uncertain about the diastolic end-point—the so called diastolic dilemma. Phase IV (muffling) may coincide with or be as much as 10 mmHg higher than phase V (disappearance), but usually the difference is less than 5 mmHg. Disappearance of sounds (phase V) should be taken as diastolic pressure. When the Korotkoff sounds persist down to zero, muffling of sounds (phase IV) should be recorded for diastolic pressure, and a note made to this effect.

Recording blood pressure
To make measurement of conventional blood pressure more informative and accurate, it is important to record the circumstances of measurement as well as the levels of blood pressure recorded. Reliability of measurement is improved if repeated measurements are made and measurement of ambulatory blood pressure or self-measurement of blood pressure, or both, gives much valuable information that cannot be obtained with measurement of conventional blood pressure.

Points to be noted

- Measurements should be noted to the nearest single mm Hg, without rounding off to the nearest 5 or 10 mm Hg
- Note state of patient (anxious or relaxed)
- Decide position of patient for measurement—lying, sitting, or standing
- Decide on arm (right or left) in which to measure blood pressure; readings should be taken in both arms at the first visit
- Note arm circumference
- Note inflatable bladder dimensions
- Identify Korotkoff phases IV and V for diastolic pressure
- Note presence of auscultatory gap
- Note time of drug ingestion, if appropriate
- At least two measurements should be taken at each visit at intervals of at least one minute

Korotkoff sounds

- **Phase I**—the first appearance of faint, repetitive, clear tapping sounds that gradually increase in intensity for at least two consecutive beats is the systolic blood pressure
- **Phase II**—a brief period may follow phase 1, 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 that become crisper to regain, or even exceed, the intensity of the sound in phase I. The clinical significance, if any, of 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

Manometer position

- Manometer <3 feet from observer
- Mercury column should be vertical
- Mercury column at eye level—standard mounted models can be adjusted to suit the height of the observer
- Observer's eye should follow the level of the mercury meniscus
- Aneroid scale must be viewed straight on with eye on a line perpendicular to the centre of the face of the gauge

Steps in measurement

- Place the stethoscope gently over the brachial artery at the point of maximal pulsation
- Hold stethoscope firmly and evenly but without excessive pressure—excess pressure may distort artery and produce sounds below diastolic pressure
- Stethoscope end-piece should not touch clothing, cuff, or rubber tubes to avoid friction sounds
- Inflate cuff rapidly to about 30 mm Hg above palpated systolic pressure
- Deflate cuff at a rate of 2 to 3 mm Hg per pulse beat (or per second) during which the Korotkoff sounds will be heard
- Deflate cuff rapidly after all sounds disappear
- Make sure cuff is completely deflated before repeating measurement so as to avoid venous congestion of the arm