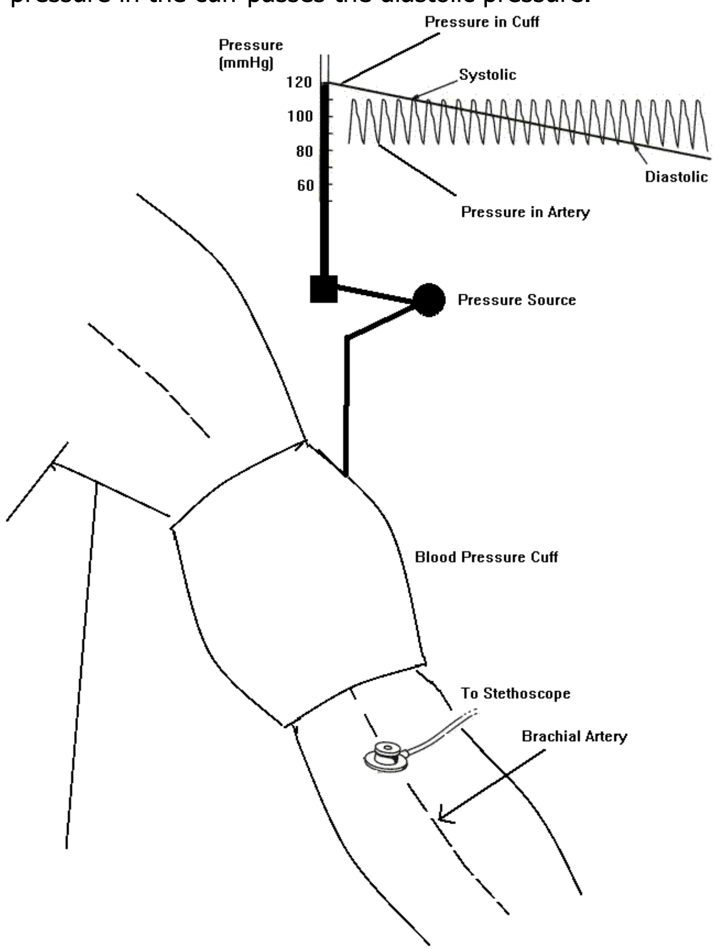
2.6 Blood Pressure Machines

2.6.1 Clinical Use and Principles of Operation

Blood pressure machines are one of the primary diagnostic tools used by health care workers. Sphygmomanometers are used for determining the patient's resting blood pressure, one of the preliminary tests that health care workers may perform. A diagnosis of high or low blood pressure can be indicative of other, more serious diseases. There are three main types of blood pressure machines: mercury, aneroid, and electronic.

The measurement of blood pressure has been common for over a century and is often misunderstood. The non-invasive measurement of blood pressure is accomplished by occluding an artery in the upper arm with an inflatable cuff that is connected to a mercury manometer. A stethoscope is used to listen for the Korotkoff's sounds as the blood flows. The first sound is heard as the pressure in the cuff passes the systolic pressure. The last sound is heard as the pressure in the cuff passes the diastolic pressure.



A traditional blood pressure measurement is made by occluding the brachial artery with a cuff. As the cuff is deflated, the technician can hear, at first, nothing, as no blood flows in the artery, then a sound as the pressure in the cuff is just below the systolic (maximum) pressure. When the cuff pressure just descends below the diastolic (minimum) pressure, the sound goes away because the flow returns to laminar flow.

The ideal pressure is 120 mmHg systolic and 80 mmHg diastolic. Systolic pressures above 150 mmHg or diastolic pressures above 100 mmHg are of clinical concern. The difference between the systolic and diastolic pressures is called the pulse pressure. This generally runs between 40 and 50 mmHg. An estimated mean pressure can be obtained by adding one third of the pulse pressure to the diastolic pressure. The mean pressure shouldn't drop below about 80 mmHg.

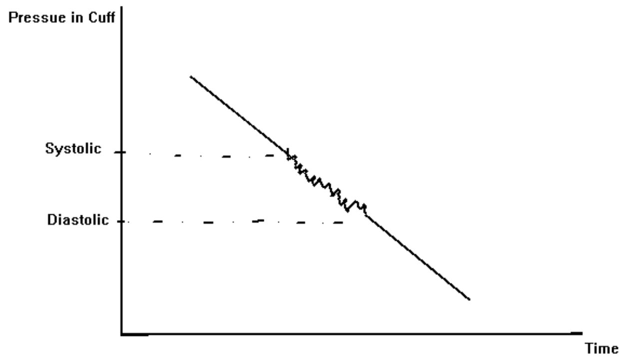
To measure the pressure in the cuff, a mercury manometer is often used. A plastic or glass column with graduations from 0 to 300 mm is connected to the cuff via latex or rubber tubing. The tube is filled with mercury. The pressure reading is the height of the mercury column. To get accurate readings the tube must be exactly vertical. At the top of the tube, under the cap is a calf skin diaphragm that allows air to move in both directions. If this diaphragm is dirty the mercury in the column will not move smoothly, either up or down. Mercury manometers are no longer used in The United States. However, they are quite common in the developing world.

In this photo, the cover for the mercury reservoir has been removed (right). The mercury has oxidized leaving a fine powder that should be removed before refilling the reservoir.

Another manometer used for blood pressure readings is the aneroid manometer. This is a bellows based system that has a dial calibrated in the range of 0 to 300 mmHg. At the resting point of the needle on the dial is a rectangular box. If the needle is in that box the manometer is calibrated and can be used.

An aneroid manometer uses a calibrated dial. Notice that when the dial is at zero, there is a small rectangle where the needle should rest. This manometer is also calibrated in inches of water.

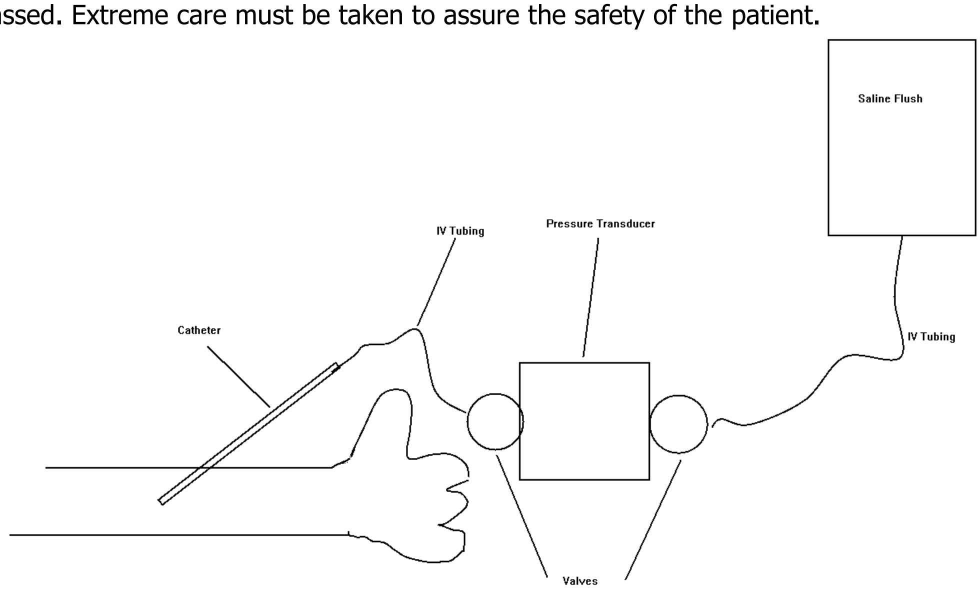
Non-invasive blood pressure machines (NIBP) are devices that automatically and electronically measure blood pressure. In these system electronics replaces a human in the inflation/deflation of the cuff. In most modern devices, the detection of the pulsation, not the listening for Korotkoff sounds, drives the detection of the maximum and minimum pressure. The results are displayed in digital format on separate displays or on a screen. The units can be programmed to take blood pressures on a set cycle, 1, 5, 15, 30 minutes, trend the data and often sound alarms if the results are outside of preset limits.



Automatic non-invasive blood pressure (NIBP) machines typically measure the presence of small oscillations in the pressure to determine the systolic and diastolic pressures. Some older machines may use a sensor to detect the Korotkoff sounds.

Older NIBP's may use two tubes to inflate the blood pressure cuff. Some devices have a transducer in the cuff to detect the sounds.

A completely different approach to measuring blood pressure is to invasively introduce a catheter into an artery. This is most common in surgery and intensive care units. The blood pressure device is connected to the catheter via a rigid wall plastic tube filled with a saline solution. The tube is connected to a transducer, which may be connected to bag of saline or "flush." Figure 2.7.3 illustrates the set up. The transducer is hung at the level of the heart. The output from the transducer is amplified and displayed as numbers, waveform or both. Since the skin has been breached the patients first line of defense for both infection and electrical shock have been bypassed. Extreme care must be taken to assure the safety of the patient.



An invasive blood pressure measurement typically involves piercing the skin of the arm or leg. The pressure transducer should always be at the level of the patient's heart. The flush bag is held a foot or more above the patient.

2.6.2 Common Problems

Non-invasive, manual blood pressure machines are extremely reliable. They are also inexpensive. Even in the developing world, they are often replaced rather than repaired. However, there are a few common problems.

Leaks in the tubing are common and can often be repaired with epoxy or silastic. To check for leaks, inflate the cuff to 250 mmHg and allow it to stand. The pressure should slowly decrease at a rate not exceeding 5 mmHg per minute. If there is a leak, you can find it by rubbing soapy water over the tubing and looking for bubbles.

User errors related to calibration are somewhat common. The cuff must be at the level of the heart and the manometer must read zero before the cuff is inflated. Check the cleanliness of the mercury. After a time, mercuric oxide will form and is distinguishable by a black powder. The mercury, the mercury reservoir, and tube will all need to be cleaned. Keep in mind that mercury is toxic and care should be used to not release any into the ground or building. Check the leather seal and washer located at the top of the upright tube. Pump the pumping bulb: as soon as the pumping is stopped, the mercury should stop rising. If it continues to rise, the leather seal and washer will have to be further investigated and perhaps replaced.

For automatic NIBP's the most common problem is the use of the incorrect cuff. If the correct cuff is being used, and if the transducer is located in the cuff itself, it may be possible to access the transducer with some difficulty. However, repair often requires specialized knowledge, as the manufacturer's designs vary considerably.

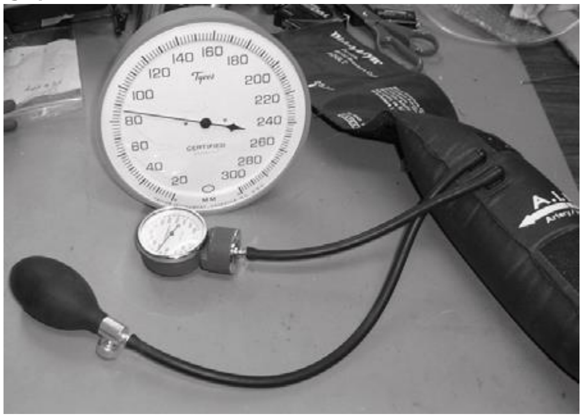
For invasive blood pressure measurements, there are many possible problems. The most common is reusing non-reusable transducers. The single use disposable transducers are now the standard of care in the United States. While there are non-disposable alternatives, they are rarely used. The transducer is commonly mounted on an IV pole next to the patient's bed. It should be at the same level as the patient. There is a 2.5 mmHg error for every inch that the transducer is above or below the level correct level.

During the set-up process the invasive catheter transducer is vented to air, zeroed and all the air removed from the line, usually using the flush solution. The technician may, or may not correctly complete each of these steps, leaving air bubbles in the line or leaving the transducer improperly zeroed. Also check that the transducer is at the level of the heart.

2.6.3 Suggested Minimal Testing

The most critical element to calibrate is the pressure measurement. A simple pressure standard can be made by creating a column of water in a tube. Taping a tube to the wall and filling it with water up to a height of 271 cm, for example, creates a pressure standard of 200 mmHg (the density of mercury is 13.55 times that of water). Before releasing the blood pressure machine, check several pressure levels (200 mmHg, 100 mmHg and 50 mmHg – or 271 cm H20, 136 cm H20 and 68 cm H20, respectively). The manometer should be accurate to within 1-3 mmHg.

A manometer can be tested against a known good manometer, against a mercury manometer, or against a simple column of water in an IV tube (100 mmHg of pressure is exerted by a column of water 135 cm high).



If the pressure is consistently too high or too low, you will need to adjust the zero by removing or adding mercury or twisting the manometer face (if aneroid). Electronic blood pressure devices will have a zero setting which should never need to be adjusted, if the device is properly zeroed before each use. There is a gain setting for electronic devices that occasionally needs to be adjusted.

If the blood pressure machine is intended for manual use, you should also check the device for convenience of use. When inflated with the valve closed, the pressure should not drop appreciably in ten seconds. When the valve is open, the pressure should drop slowly and linearly. Consult with the physician or nurse about the leak and drop rates to be sure that the device will be convenient for them to use.

If a mercury manometer has been used for many years, mercuric oxide may form in the tube and will appear as a black powder. The mercury, tube, and reservoir will all have to be cleaned if the nurse objects to its presence. Keep in mind that mercury is toxic and should not be touched or the vapors excessively inhaled. To remove the mercuric oxide, take off the reservoir cap and remove the mercury using a needle and syringe. Filter the mercury through filter paper into a clean container. Repeat several times until all the solid oxide is removed. Take the tube and reservoir outside and use an air line to blow out any particulate matter. Replace the clean mercury into the reservoir and top off the reservoir with new mercury up to the '0' mark. Replace the reservoir cap.

Automatic, non-invasive blood pressure machines (NIBP's) are more difficult to calibrate than the others because the need to detect the Kortokoff sounds to function. If you do not have a phantom arm, then the best approach is to use your own arm. Borrow a stethoscope and measure your own BP. If you are not confident that you can use a sphygmomanometer accurately, then ask someone else to measure your BP. Repeat the measurement five times. Then connect yourself to the NIBP and measure your blood pressure five times. The average diastolic and systolic pressures from the two systems should match to within 3 mmHg.