ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
Approved by AICTE and affiliated to Anna University Chennai (An ISO Certified Institution)
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DEPARTMENT OF BIOMEDICAL ENGINEERING

BM3491 Biomedical Instrumentation

UNIT-IV MEASUREMENT OF BIO SIGNALS

4.2 Blood Pressure Measurement

Blood pressure is the most often measured and the most intensively studied parameter in medical and physiological practice. The determination of only its maximum and minimum levels during each cardiac cycle supplemented by information about other physiological parameters. It is an invaluable diagnostic aid to assess the vascular condition and certain other aspects of cardiac performance. Pressure measurements are a vital indication in the successful treatment and management of critically ill patients in an intensive cardiac care or of patients undergoing cardiac catheterization.

Blood is pumped by the left side of the heart into the aorta, which supplies it to the arterial circuit. Due to the load resistance of the arterioles and precapillaries, it loses most of its pressure and returns to the heart at a low pressure via highly distensible veins. The right side of the heart pumps it to the pulmonary circuit, which operates at a lower pressure. The heart supplies blood to both circuits as simultaneous intermittent flow pulses of variable rate and volume.

Blood pressure is the measure of the pressure developed against the wall of the arteries by the circulating blood. It is the measure of the pressure of the blood in the major arteries during the systole and diastole stages of the cardiac cycle. It is also called the *systemic arterial pressure*.

- A single cycle of cardiac activity can be divided into two basic phases *diastole and systole*.
- During the **contraction phase (systole),** blood is ejected from both the left and right ventricles and pumped into the systemic circulation and pulmonary circulation, respectively.

❒ During the **relaxation phase of the heart (diastole),** the ventricles are filled with blood in preparation for the next contraction phase

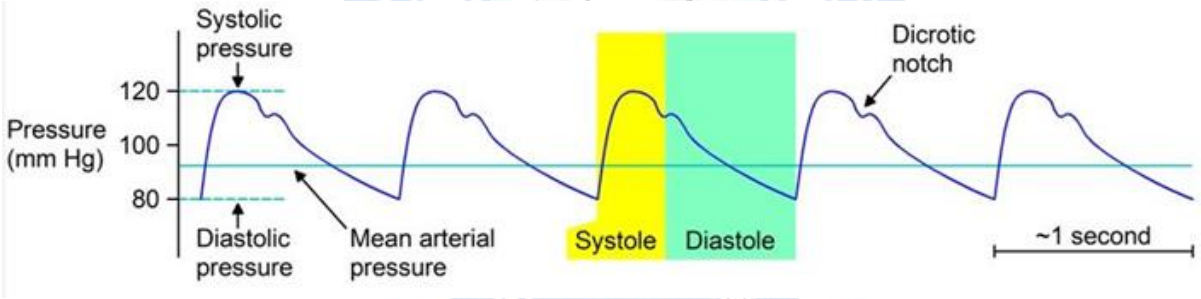
The maximum pressure reached during cardiac ejection is called ***systolic pressure*** and the minimum pressure occurring at the end of a ventricular relaxation is termed as ***diastolic pressure***.

The mean arterial pressure over one cardiac cycle is approximated by adding one-third of the pulse pressure (difference between systolic and diastolic values) to the diastolic pressure.

$$MAP = (2/3)\,DBP + (1/3)$$

$$PP = SBP - DBP$$

$$MAP = DBP + \frac{1}{3}PP$$



The nominal values in the basic circulatory system are as follows:

- ❒ Arterial system 30–300 mmHg
- ❒ Venous system 5–15 mmHg
- ❒ Pulmonary system 6–25 mmHg

Blood pressure is usually reported as "*Systolic over Diastolic*"; e.g. *120/80* is a systolic pressure of 120 mmHg and a diastolic pressure of 80 mmHg.

There are two basic methods for measuring blood pressure—

1. **Direct Method**

   Needles or catheters are introduced into peripheral arteries of patients and arterial blood pressure is measured directly by means of strain gauges
2. **Indirect Method**

In the majority of cases, blood pressure is estimated indirectly by means of a sphygmomanometer.

4.2.1 Indirect Methods of Monitoring Blood Pressure:

The most popular indirect method involves **sphygmomanometers**.

Different methods of Indirect Blood Pressure Measurements are,

- ❑ Korotkoff Sound Method
- ❑ Auscultatory Method
- ❑ Oscillometric Method
- ❑ Rheographic method

4.2.1.1 Auscultatory Method (Sphygmomanometer):

A sphygmomanometer, consist of an

- ✓ Inflatable rubber bladder called the cuff,
- ✓ Stethoscope
- ✓ Rubber squeeze-ball pump-and-valve assembly, and
- ✓ a manometer. (The manometer might be an actual mercury column (as shown), or a dial gage.)

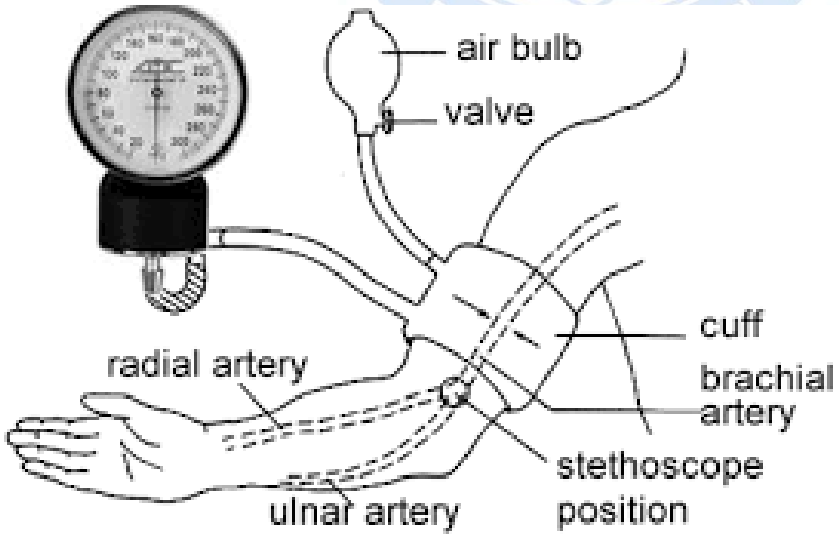


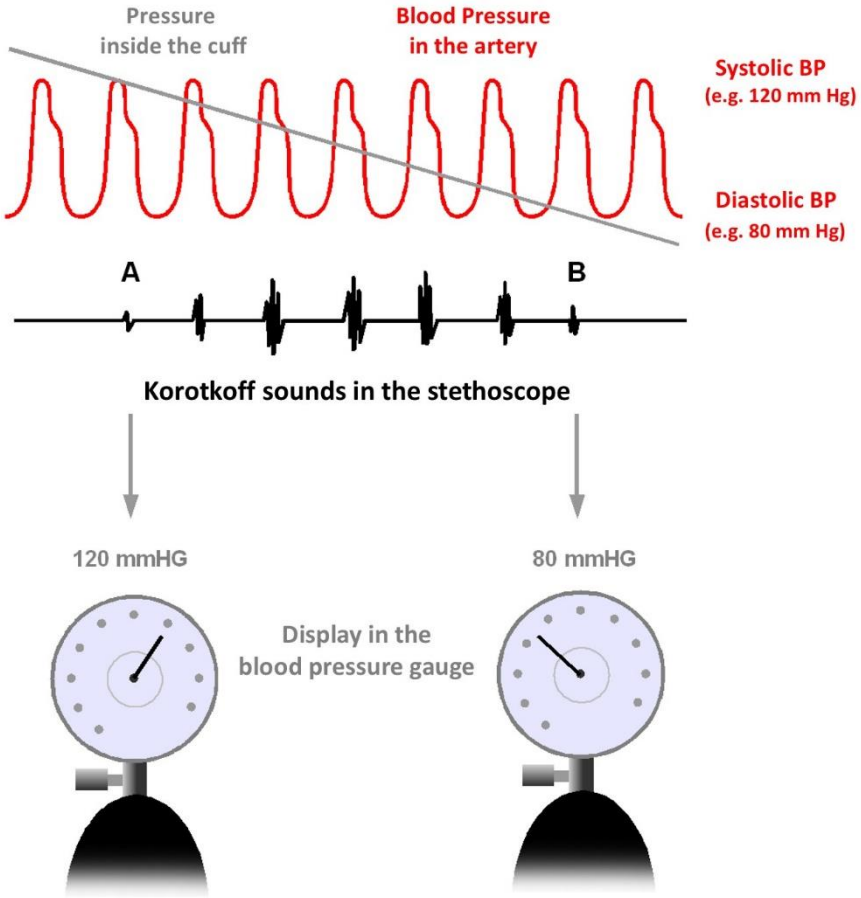
Fig.4.1 Aneroid Sphygmomanometer

Fig. 4.2 Mercury manometer and pressure cuff

- The auscultatory technique is a non-invasive method for accurately measuring blood pressure.
- It consists of an inflatable rubber bladder called the cuff, a rubber squeeze-ball pump and valve assembly, and a manometer.
- The **procedure** for using this apparatus is:
  1. The ***cuff is wrapped*** around the patient's upper arm at a point about midway between the elbow and shoulder.
  2. The ***stethoscope*** is placed over an artery distal (i.e., downstream) to the cuff. This placement (see Figure) is preferred because the brachial artery comes close to the surface near the antecubital space (i.e., "'inside'' of the elbow) and so is easily accessible.
  3. The ***cuff is inflated*** so that the pressure inside the inflated bladder is increased to a point greater than the anticipated systolic pressure.
  4. This pressure compresses the artery against the underlying bone, causing an occlusion that ***shuts off the flow of blood*** in the vessel.
  5. Then ***slowly release*** (i.e., reduces) the pressure in the cuff (about ***3 mm Hg/s i***s usually deemed best) and watches the pressure gage or mercury column.
  6. When the systolic pressure first exceeds the cuff pressure, the operator begins to hear some crashing, ***snapping sounds*** in the stethoscope that are caused by the first jets of blood pushing through the occlusion. These sounds, called ***Korotkoff sounds***.
  7. Continue as the ***cuff pressure diminishes***, becoming ***less loud*** as the blood flow' through the occlusion becomes smoother. **Korotkoff sounds disappear** or become muffled when the cuff pressure drops below the patient's diastolic pressure.
  8. To read the blood pressure, the operator notes both the ***gage pressure*** at the onset of ***Korotkoff sounds*** (systolic) and also when the sounds become muffled (or disappear) altogether (diastolic). These pressures are usually re-corded in the ratio of systolic over diastolic (i.e., 120/80).

The use of Korotkoff sounds as the indirect indicator of blood pressure is also called auscultation (i.e., use of hearing). The mechanism of Korotkoff sounds may not be a

sound waves at all, but vibrations of the arterial walls that transmits into surrounding tissues.



Blood pressure measurement using the auscultatory method based on the (first) Korotkoff-sound

4.2.1.2 Limitations of ausculatory method:

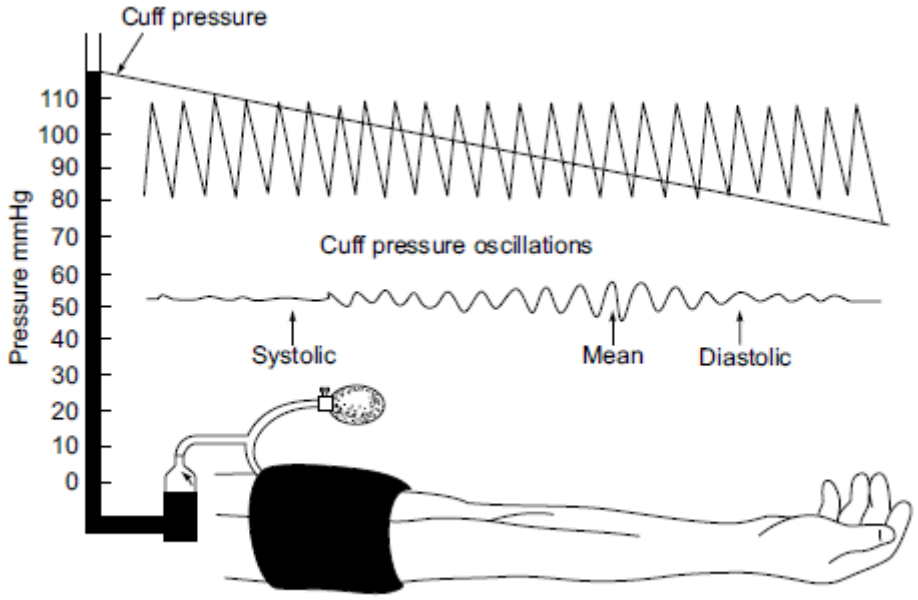
1. Hearing acuity of the operator and how accurately the operator is able to read a changing pressure gage when the Korotkoff sound features are heard.
2. In hypotensive (i.e., low blood pressure) patients, the event chosen to indicate the diastolic pressure may be either obscured or nonexistent.

4.2.1.3 Oscillometric Method of Blood Pressure Measurement:

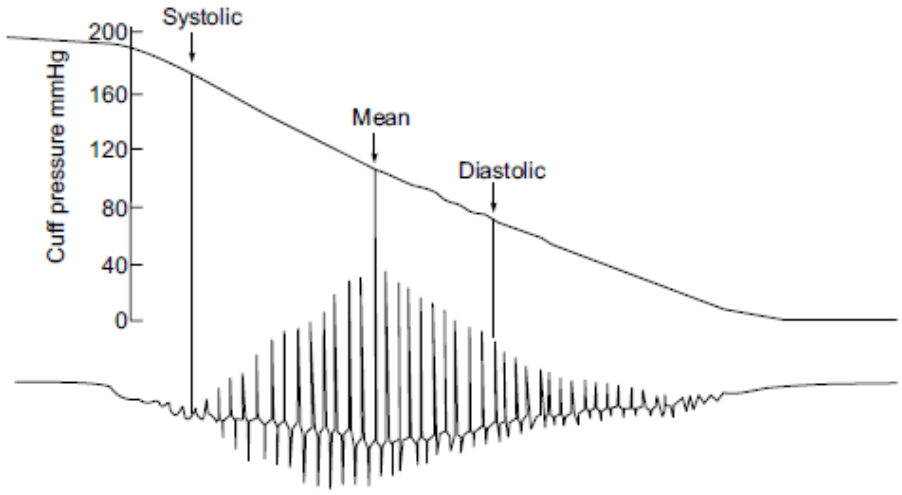
The oscillometric method of blood pressure measurement is very similar to ordinary spygmomanometry, except that we measure small fluctuations (i.e., oscillations) in the cuff pressure rather than direct pressure.

Working Principle:

- ❒ When the occluding cuff deflates from a level above the systolic pressure, the artery walls begin to vibrate or oscillate and the blood flows turbulently through the partially occluded artery
- ❒ These vibrations will be sensed in the transducer system monitoring cuff pressure.
- ❒ When the pressure in the cuff further decrease, the oscillations increase to a maximum amplitude and then decrease until the cuff fully deflates and blood flow returns to normal.



(a) Oscillometric method



(b) Oscillations in cuff pressure

- The cuff pressure at the point of maximum oscillations usually corresponds to the mean arterial pressure.
- When blood breaks through the occlusion created by the inflated cuff, which occurs when the cuff pressure drops below the systolic blood pressure, the walls of the artery begin to vibrate slightly. These vibrations are related to the fact that the blood flow at this point is turbulent, rather than laminar.
- The flucuating walls of the blood vessel slightly alter the blood pressure, giving rise to oscillations in the cuff pressure.
- The baseline-to-peak amplitude, peak-to-peak amplitude, or a quantity based on the partial or full time integral of the oscillometric pulse can be used as the oscillometric pulse index.
- The most accurate measurements taken are those of systolic and mean blood pressures with diastolic measurements being more susceptible to operator variability.
- However, diastolic pressure can be related to systolic pressure and MAP using the following formula:

$$\text{Mean BP} = \frac{\text{Systolic BP} + (2 \times \text{Diastolic BP})}{3}$$

- Most of the patient monitoring systems are based on the oscillometric measuring principle.

4.2.2 Direct Methods in Blood Pressure Measurements :

General Facts:

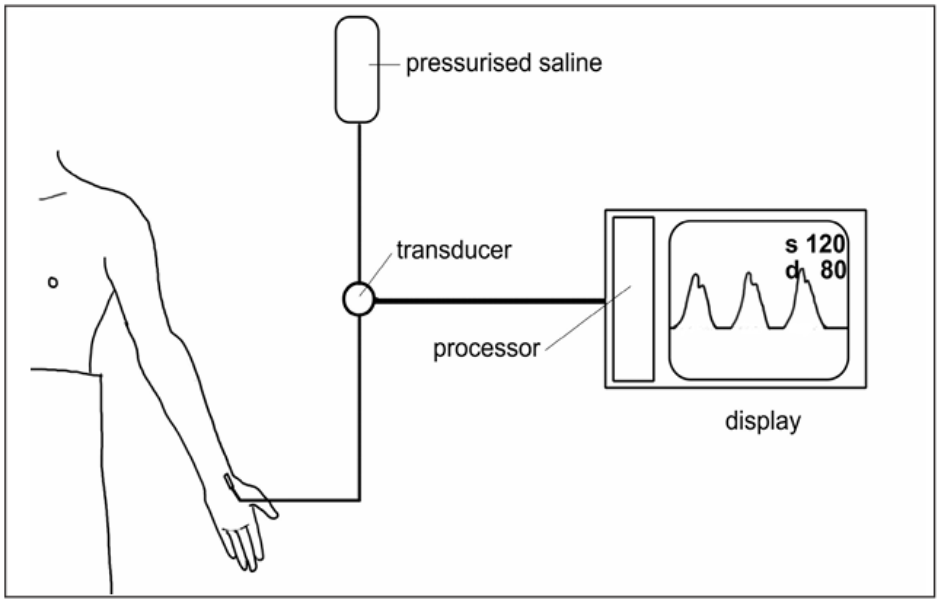
- Direct measurement = Invasive measurement
- A vessel is punctured and a catheter (a flexible tube) is guided in
- The most common sites are brachial and radial arteries but also other sites can be used e.g. femoral artery
- This method is precise but it is also a complex procedure involving many risks….

1.Extravascular Sensor:

- The sensor is located behind the catheter and the vascular pressure is transmitted via this liquid-filled catheter.

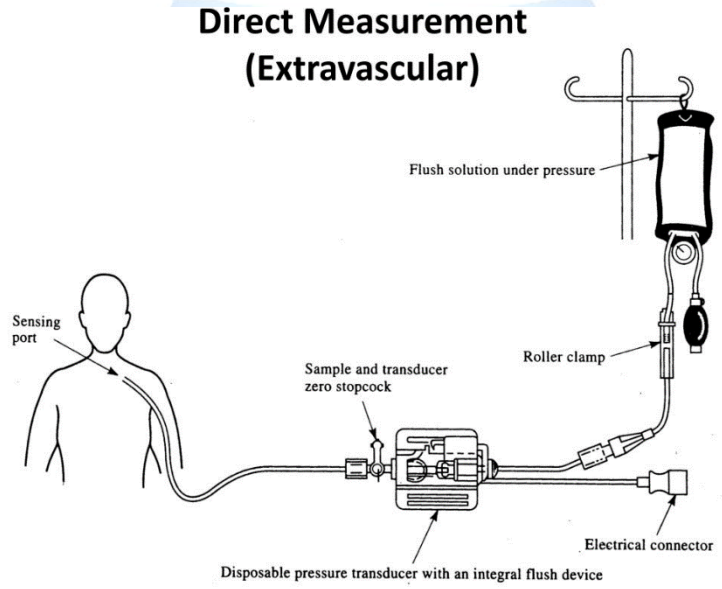
- The actual pressure sensor can be e.g.
  - ✓ strain gage
  - ✓ variable inductance
  - ✓ variable capacitance
  - ✓ optoelectronic
  - ✓ piezoelectric, etc…

- The transducer is mounted to a pole or support at bedside. There are two ports into the transducer's pressure dome; one is ''deadheaded"' and the other is connected to a hydraulic fitting called a three-way stopcock.



Components of an arterial monitoring system

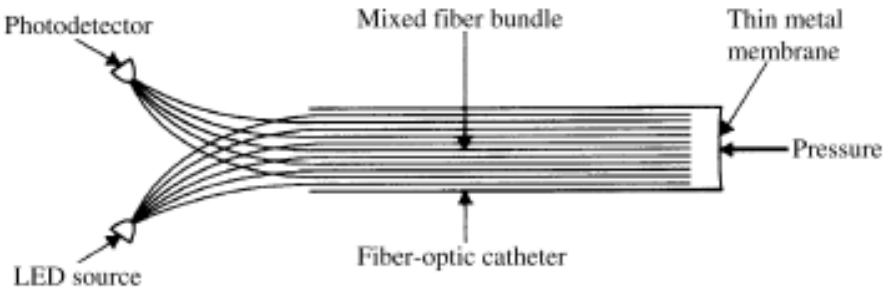
- ***One*** terminal of the stopcock goes to the ***catheter from the patient***, while the ***other*** goes to a ***small syringe*** that is used to administer medications directly to the patient through the catheter, or to withdraw arterial blood samples for laboratory analysis.

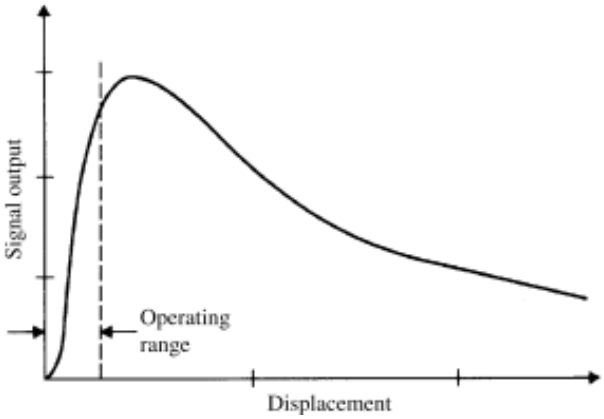


- Catheter is connected to a ***three- way stopcock*** and then to a pressure sensor
- It is filled with ***saline-heparin*** solution.
- It must be flushed with solution every few minutes to ***prevent blood clotting*** at the tip.
- Physician inserts the catheter Either by means of surgical ***cut-down***, which exposes the artery or vein.
- Or by means of ***percutaneous insertion*** which involves the use of a special needle or guide-wire technique.
- ***Blood pressure*** is transmitted via the ***catheter column*** to the ***sensor*** and finally to the ***diaphragm*** which is deflected.
- The ***displacement*** of the **diaphragm** sensed electronically.

Intravascular Sensor:

Intravascular Fiberoptic Pressure Sensor





Characteristic curve for the fiber-optic pressure sensor.

- ❒ The amount of reflection is proportional to the membrane proportional to the membrane motion which is proportional to the blood pressure.

Intravascular strain-gauge pressure sensor

Gages of this type are available in the F 5 catheter (1.67 mm OD) size. In the French scale (F), used to denote the diameter of catheters, each unit is approximately equal to 0.33 mm.

Advantage:
- Small size

Disadvantages:
- Problems of temperature
- electric drift
- Fragility
- Nondestructive sterilization
- more expensive
- break after
- High cost per use.

Electronic Manometer:

- ❑ An electronic pressure transducer can be connected to the patient through a thin piece of tubing called a catheter.
- ❒ The catheter is introduced into the vessel through a thin, hollow tube called a cannula
- ❒ The transducer's pressure diaphragm is coupled to the patient's bloodstream by a column of saline solution that fills the catheter.
- ❒ There are two general methods for inserting the catheter:

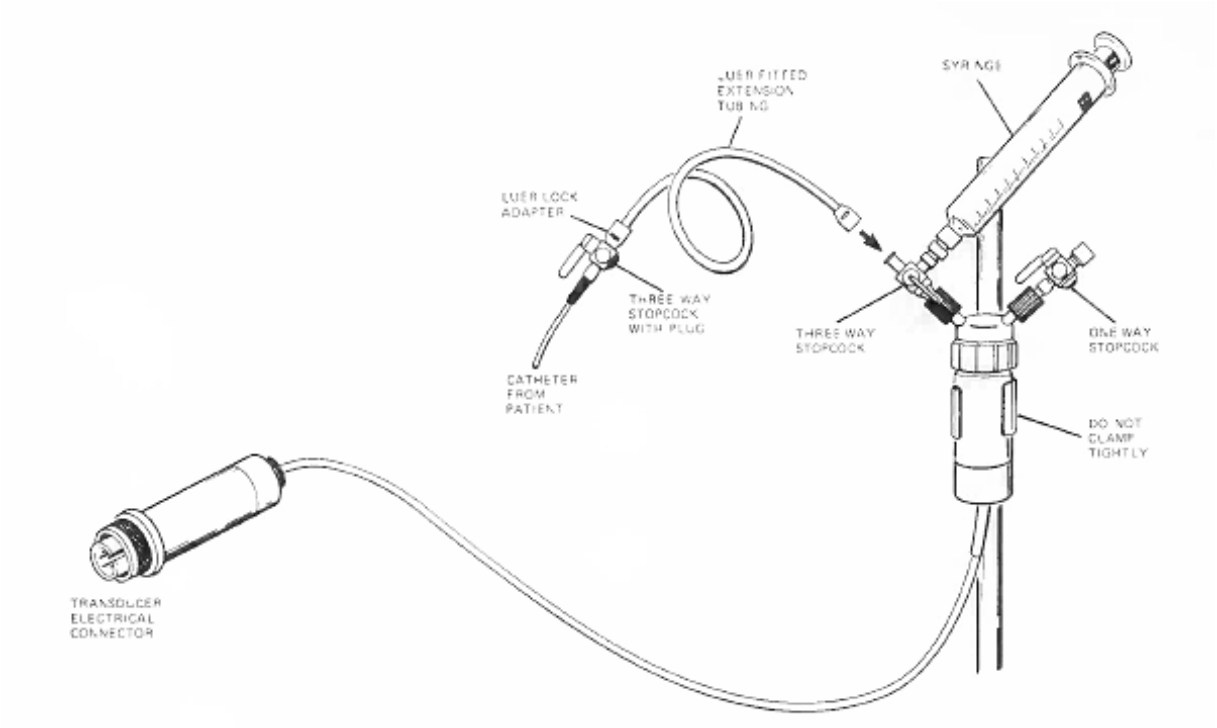
Percutaneous Insertion:

- ✓ involve puncturingthe skin over an artery and then using a needle and catheter assembly to insert the catheter into the artery.
- ✓ When the catheter is in place, the needle is withdrawn.

Surgical Cut down:

- ❒ surgical procedure in which the tissue overlying the artery is cut and laid out of the way, revealing the artery.

- A puncture is then made, and a catheter is put into place.
- The catheter to the patient must be placed inside a peripheral artery.



Typical apparatus used for measuring blood pressure with an electronic transducer.

- The transducer is mounted to a ***pole or support*** at bedside.
- There are ***two ports*** into the transducer's pressure dome;
- one is **''*deadheaded*''** and the other is connected to a hydraulic fitting called a *three-way stopcock*.
- One terminal of the stopcock goes to the ***catheter*** from the patient,
- While the other goes to a ***small syringe*** that is used to administer medications directly to the patient through the catheter, or to withdraw arterial blood samples for laboratory analysis.
- This method provides continuous and accurate blood pressure readings, making it useful in critical care settings such as ***intensive care units*** (ICUs) or during certain surgical procedures where precise blood pressure monitoring is essential. However, because it is invasive, it carries *some risks*, such as bleeding, infection, or damage to the artery.

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