BLOOD PRESSURE AND SOUND

Blood Pressure

Why blood pressure is important?

- Blood pressure is a standard clinical measurement
- Blood pressure values help physicians to determine the functional integrity of the cardiovascular system.

  - Various chambers of the hearth

How to measure blood pressure in the Human?

- Invasive (direct) and Noninvasive (indirect) techniques are used to measure blood pressure in the human body.

Sound

- “ Fluctuations in pressure recorded over the frequency range of hearing are called sounds ”
- The source of hearth sounds are the vibrations set up by the acceleration and decelerations of blood.

Function of Blood Circulation

- Transporting oxygen and nutrient to the tissues of the body and to carry metabolic waste products away from the cells.

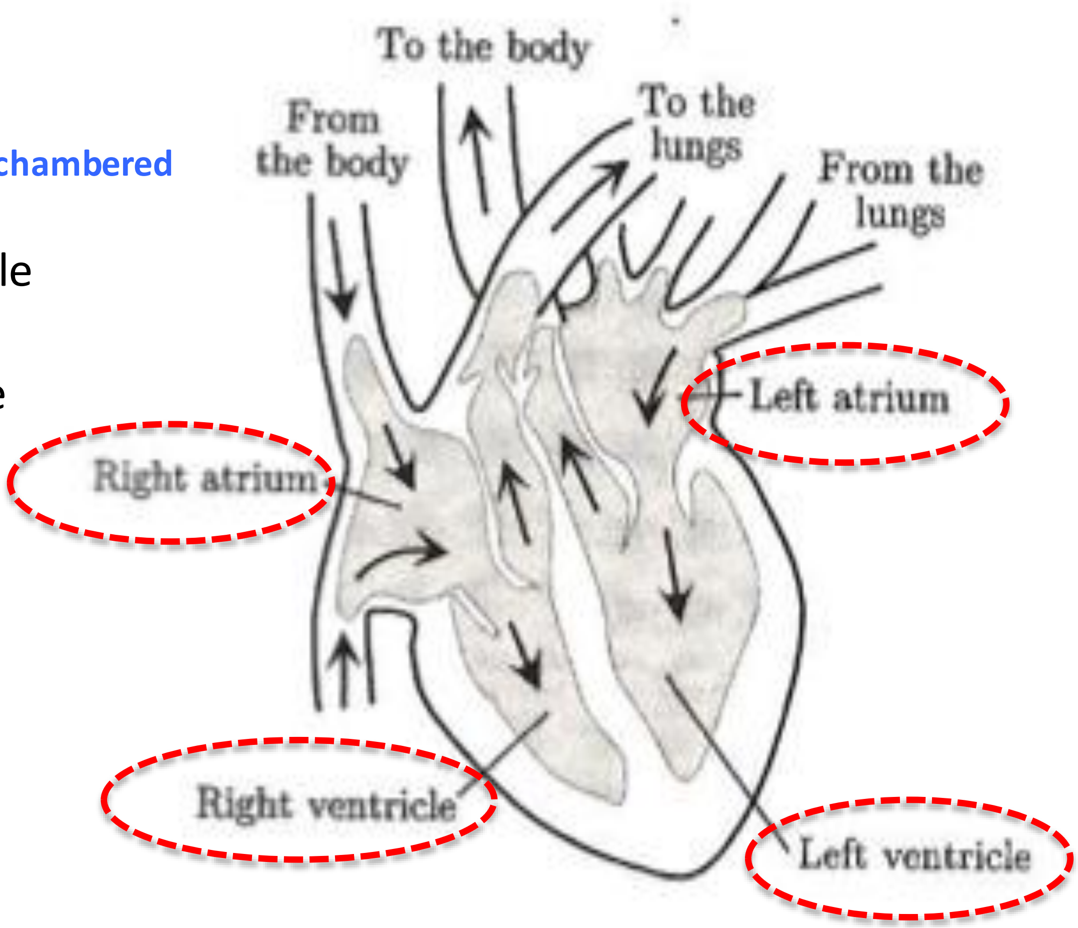
Hearth has four chambered

-right atrium

-right ventricle

-left atrium

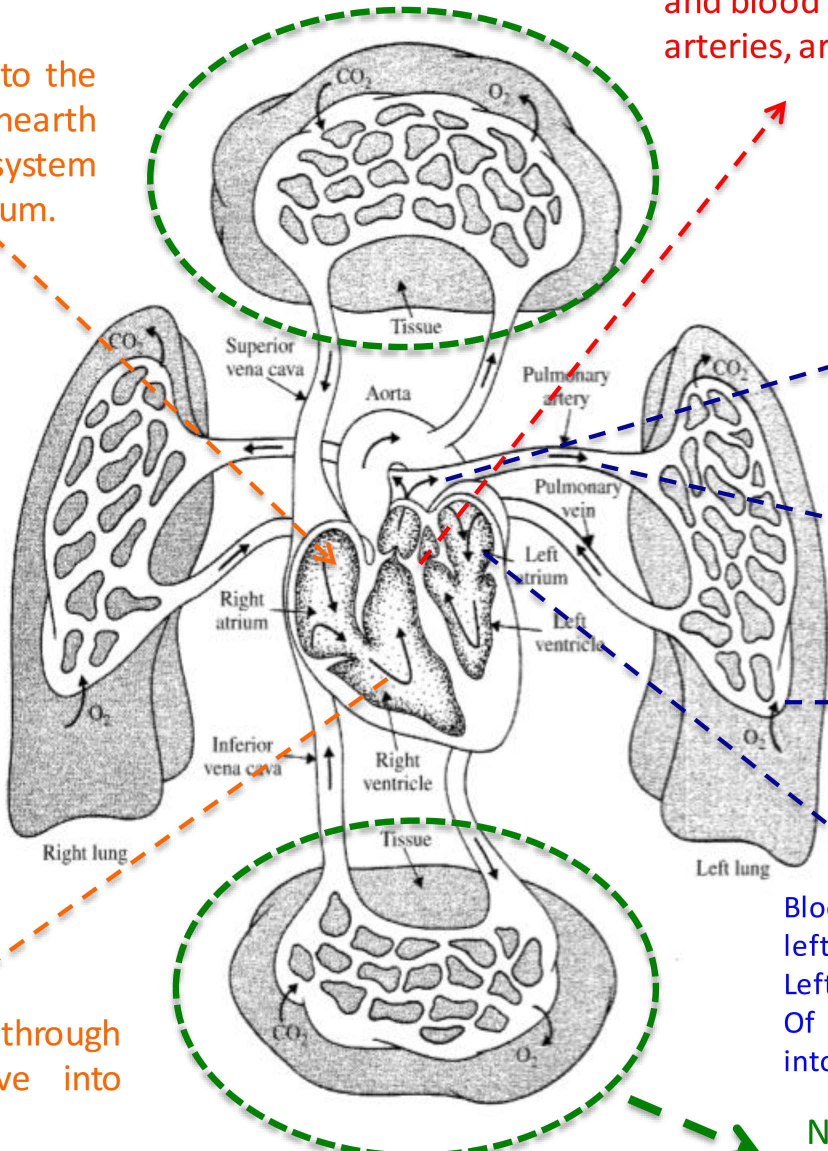
-left ventricle



Schematic Diagram of the Circulatory System

Left ventricle ejects blood through the aortic valve into aorta and blood is distributed through the branching network of arteries, arteoles and capillaries.

Blood then returns to the right side of the hearth via the venious system and fills the righ atrium.



The blood pumped from right ventricle to into the pulmonary artery through the pulmonary valve.

The blood flows through the pulmonary arteris, arterioles, capillaries.

At the pulmonary capillaries, O2 diffuses from the lung alveoli to the blood and CO2 diffuses from blood to the alveoli

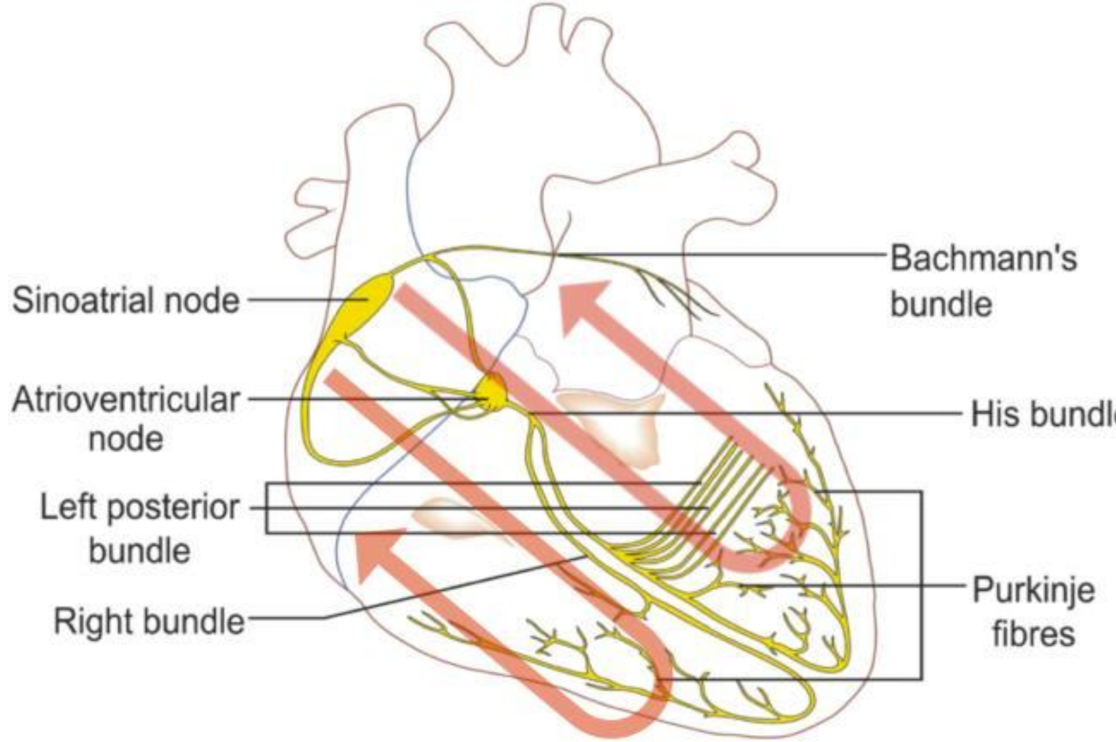
Blood veins to the left atrium and then flows to left ventricle through the mitral valve Finally, when the Left ventricle contracts in response to the electric simulation Of myocardium, blood is pumped through the aortic valve into the aorta.

Then blood flows through the tricuspid valve into right ventricle

Nutrient exchange occur between blood and tissues at the capillary level.

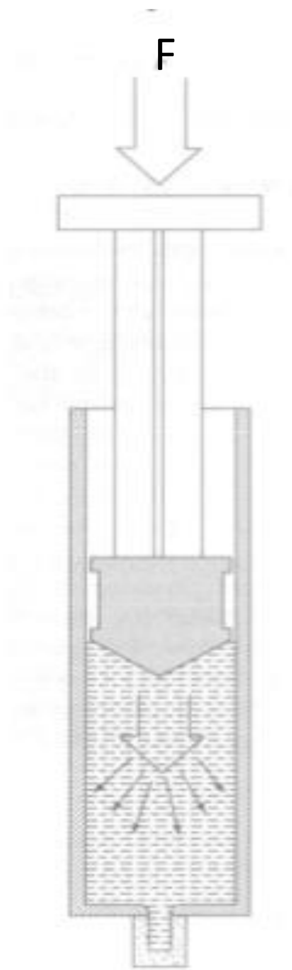
Cardiac Contraction ??

- Cardiac contraction is caused by electric stimulation of the cardiac muscle.
- An electric impulse is generated by specialized cells located in the sinoatrial node of the right atrium. This electric impulse quickly spreads over both atria.
- At the junction of the atria and ventricles, the electric impulse is conducted after a short delay at the atrioventricular node.
- Conduction quickly spreads over the interior of both ventricles by means of a specialized conduction system, the His bundle, and the Purkinje system.
- Conduction then propagates throughout both ventricles.



Blood Pressure

What is pressure?



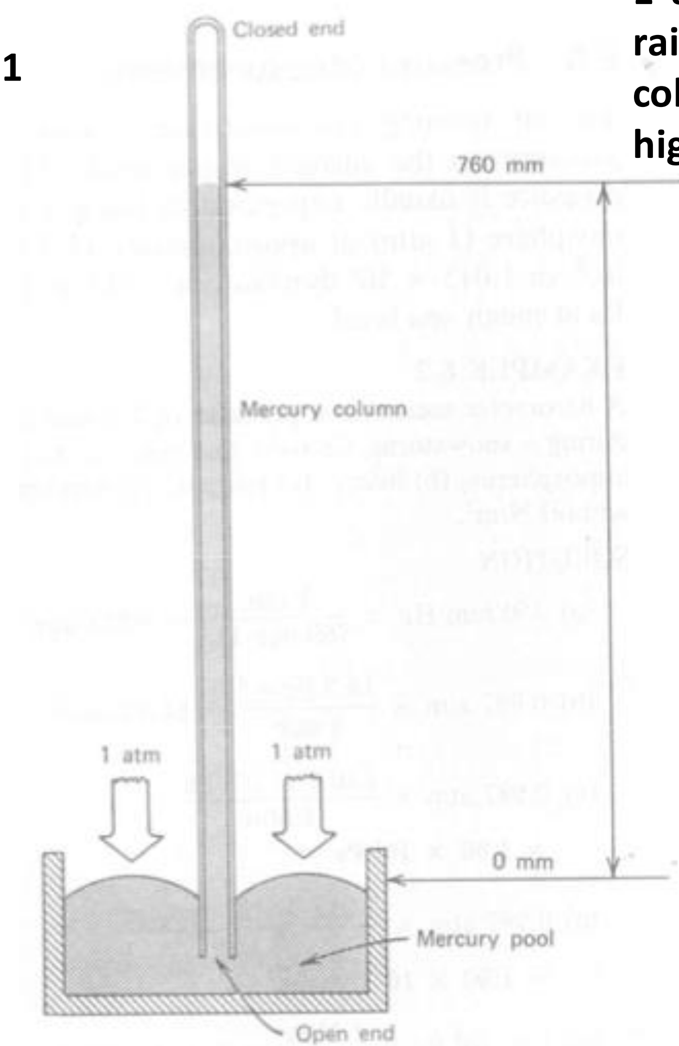
$P=F/A$

-measured in Pascal

-1 pascal= 1 Newton/ 1 m^2

Pressure exerted by plunger is distributed to all parts the fluid

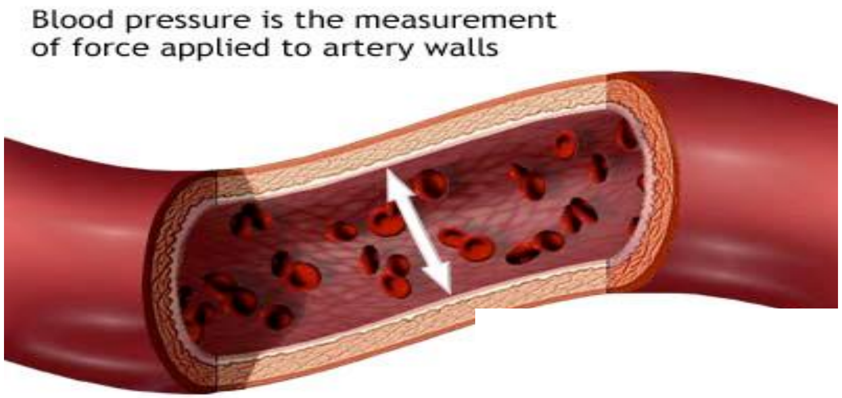
How to measure pressure?



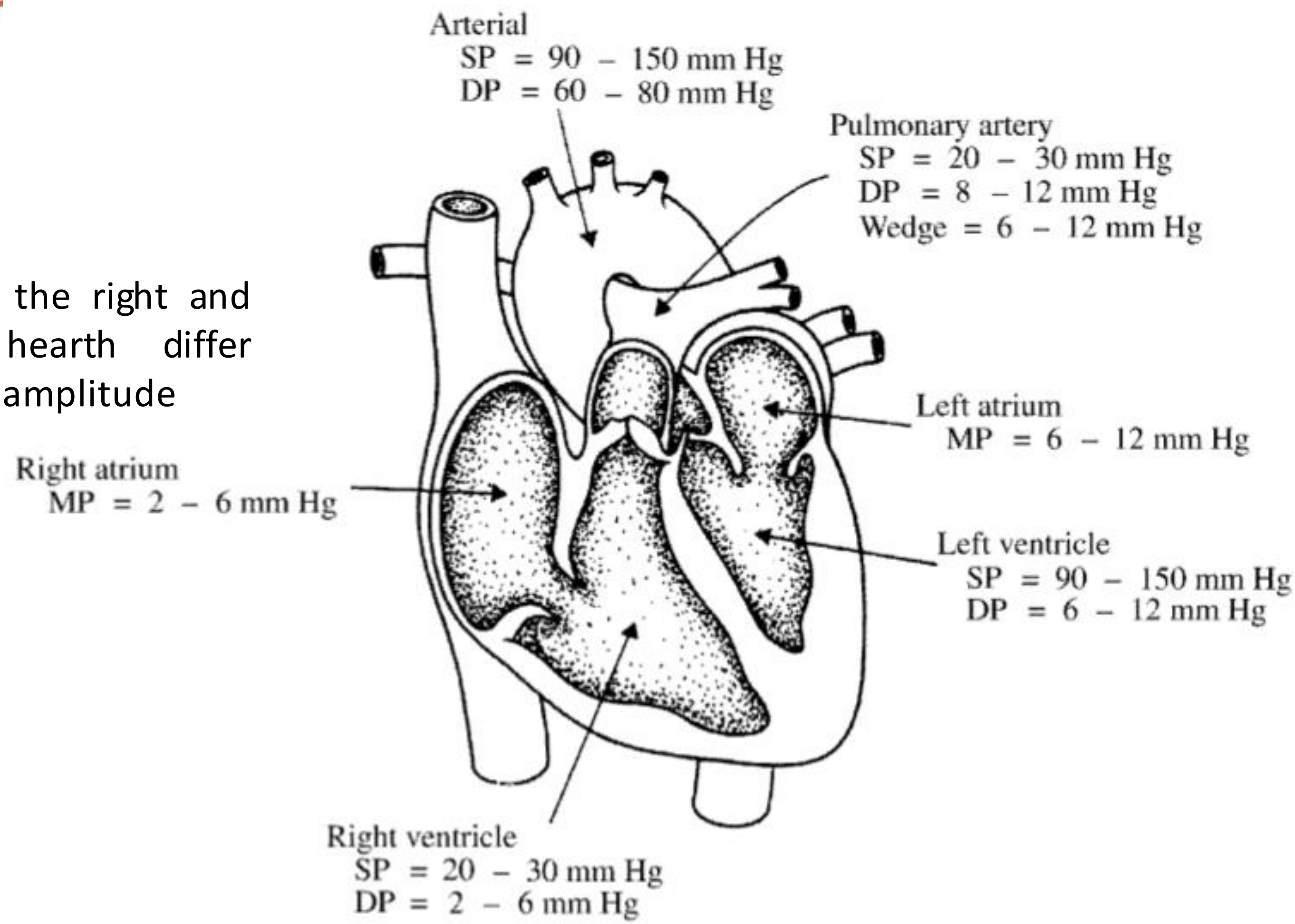
1 atm= force needed to raise mercury in coloumn about 760 mm high.

Blood pressure is measured in terms of mm-Hg

Blood Pressure



- Pressure generated by the right and left sides of the hearth differ somewhat in shape and amplitude



BLOOD PRESSURE MEASUREMENT

- We may categorize blood measurement methods in two groups:

① Invasive (Direct) Method

- ❑ **Extravascular Method**
- ❑ **Intravascular Method**

② Non Invasive (Indirect) Method

① Invasive (Direct) Blood Pressure Measuring

- Invasive (intra-arterial) blood pressure (IBP) monitoring is commonly used technique in the Intensive Care Unit (ICU) and in the operating theatre.

- This technique allows accurate blood pressure readings specially the very low pressures, for example in shocked patients.

- Blood-pressure sensor systems are are divided into general categories according to the location of the sensor:

    - **Extravascular Sensors**
    - **Intravascular Sensors**

➢ Extravascular Sensors

- The extra vascular sensor system is made up of a catheter.
- The catheter is connected to a three way stopcock and then to a pressure sensor
- It is filled with a 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 a 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.

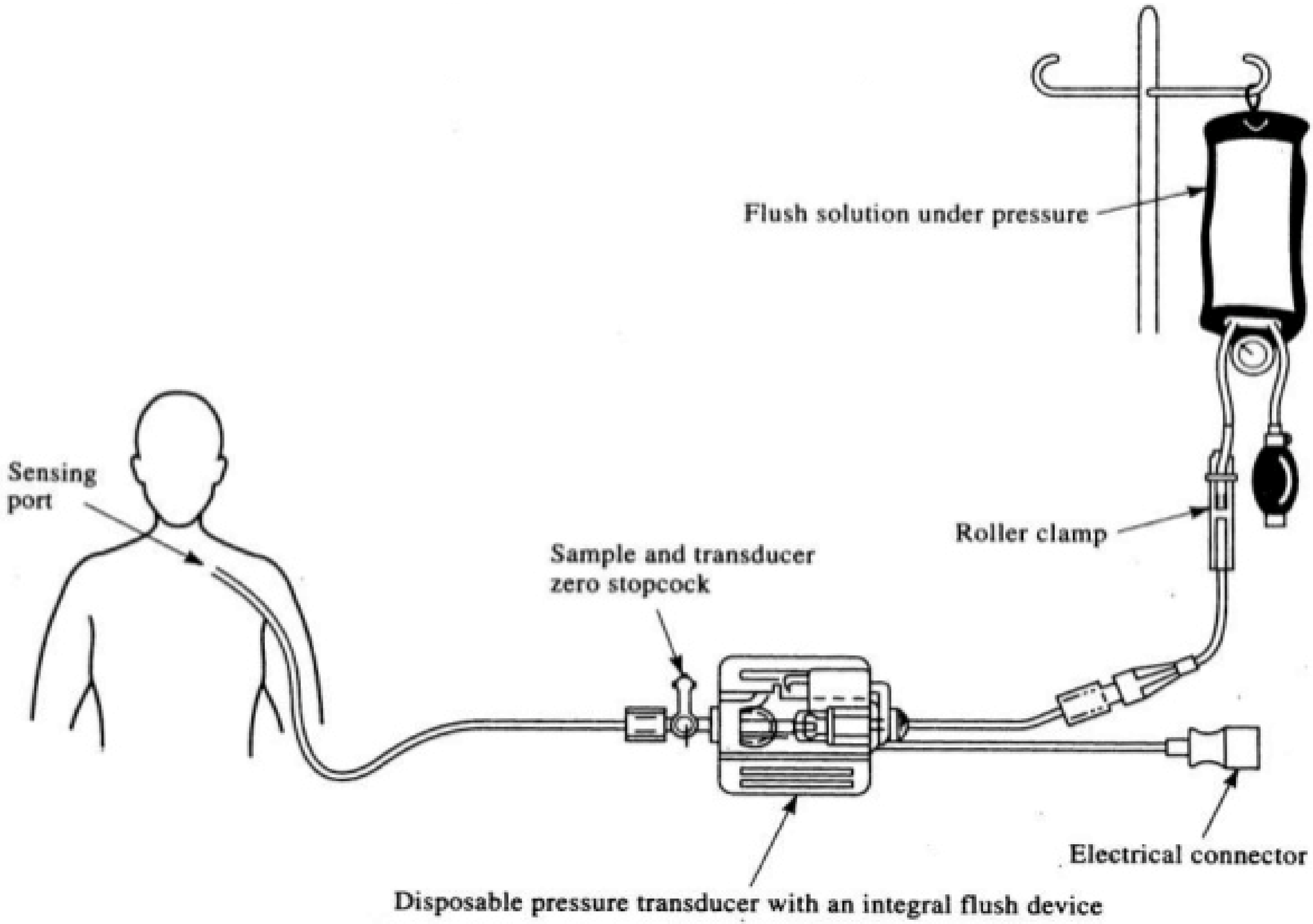
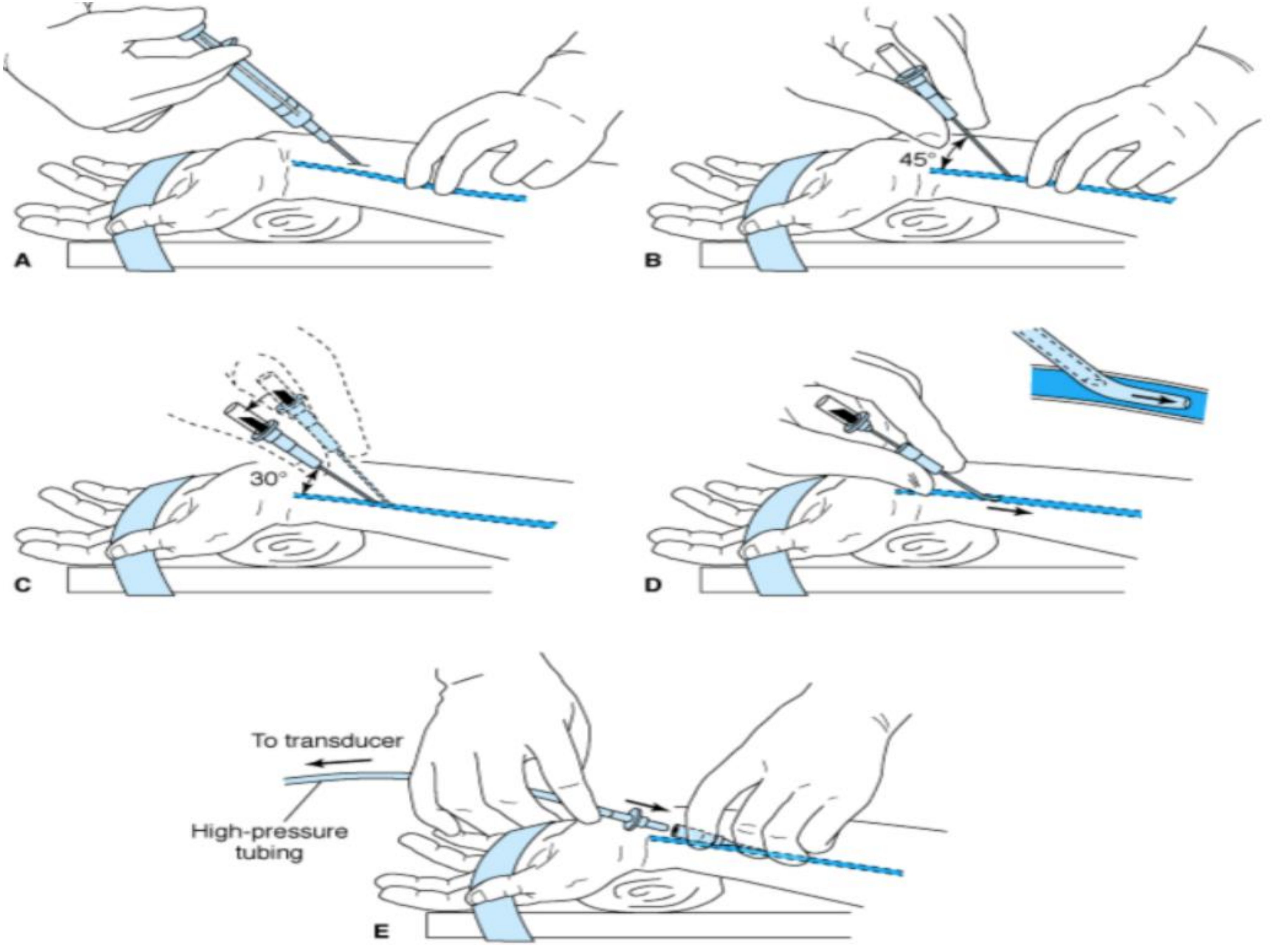


Figure 7.3 Extravascular pressure-sensor system A catheter couples a flush solution (heparinized saline) through a disposable pressure sensor with an integral flush device to the sensing port. The three-way stopcock is used to take blood samples and zero the pressure sensor.

For example: Insertion of a Radial Arterial Line



A. Local anesthetic infiltration with a 25-gauge needle after skin preparation.

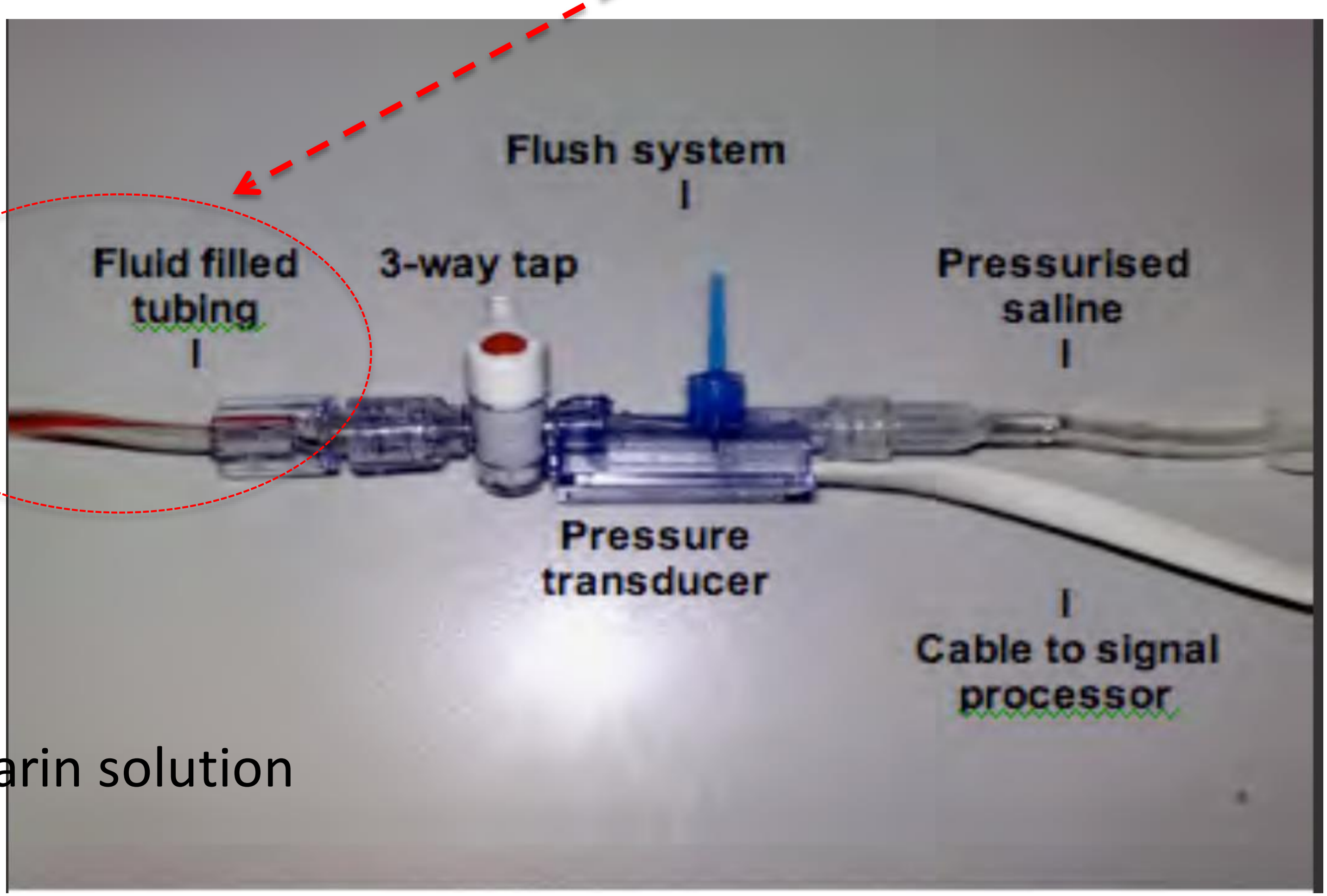
B. A 20- or 22-gauge catheter is advanced through the skin at a 45° angle.

C. Flashback of blood signals entry into the artery, and the catheter-needle assembly is lowered to a 30° angle and advanced 1–2 mm to ensure an intraluminal catheter position.

D. The catheter is advanced over the needle, which is withdrawn.

E. Proximal pressure with middle and ring fingers prevents blood loss, while the arterial tubing Luer-lock connector is secured to the intraarterial catheter.

- Blood pressure is transmitted via the catheter column to the sensor and finally to the diaphragm which is deflected.



saline-heparin solution

conducts the pressure wave to the transducer

Disposable blood-pressure sensor system

- By micromachining silicon, a pressure diaphragm is etched and piezoresistive strain gages are diffused into the diaphragm for measuring its displacement. This process results in a small, integrated, sensitive, and relatively inexpensive pressure sensor.
- This silicon chip is incorporated into a disposable pressure-monitoring tubing system.

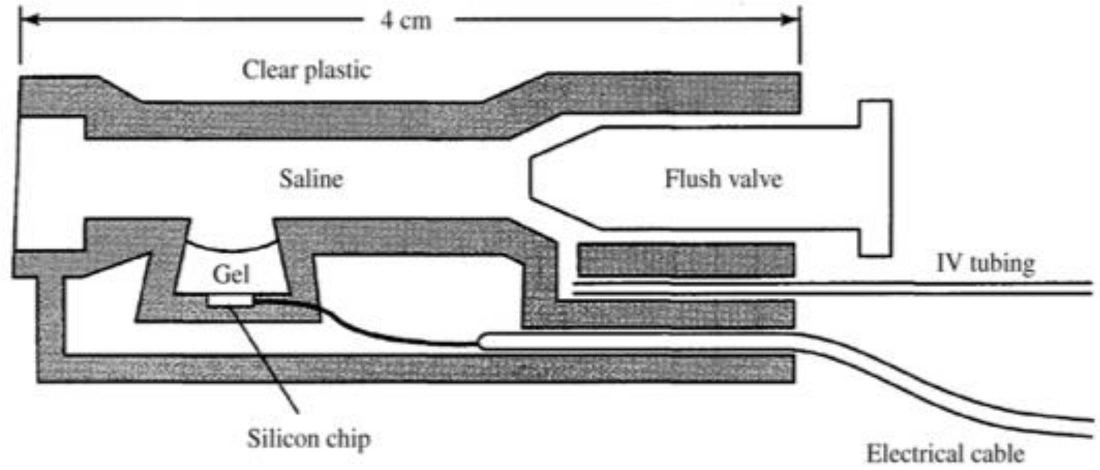
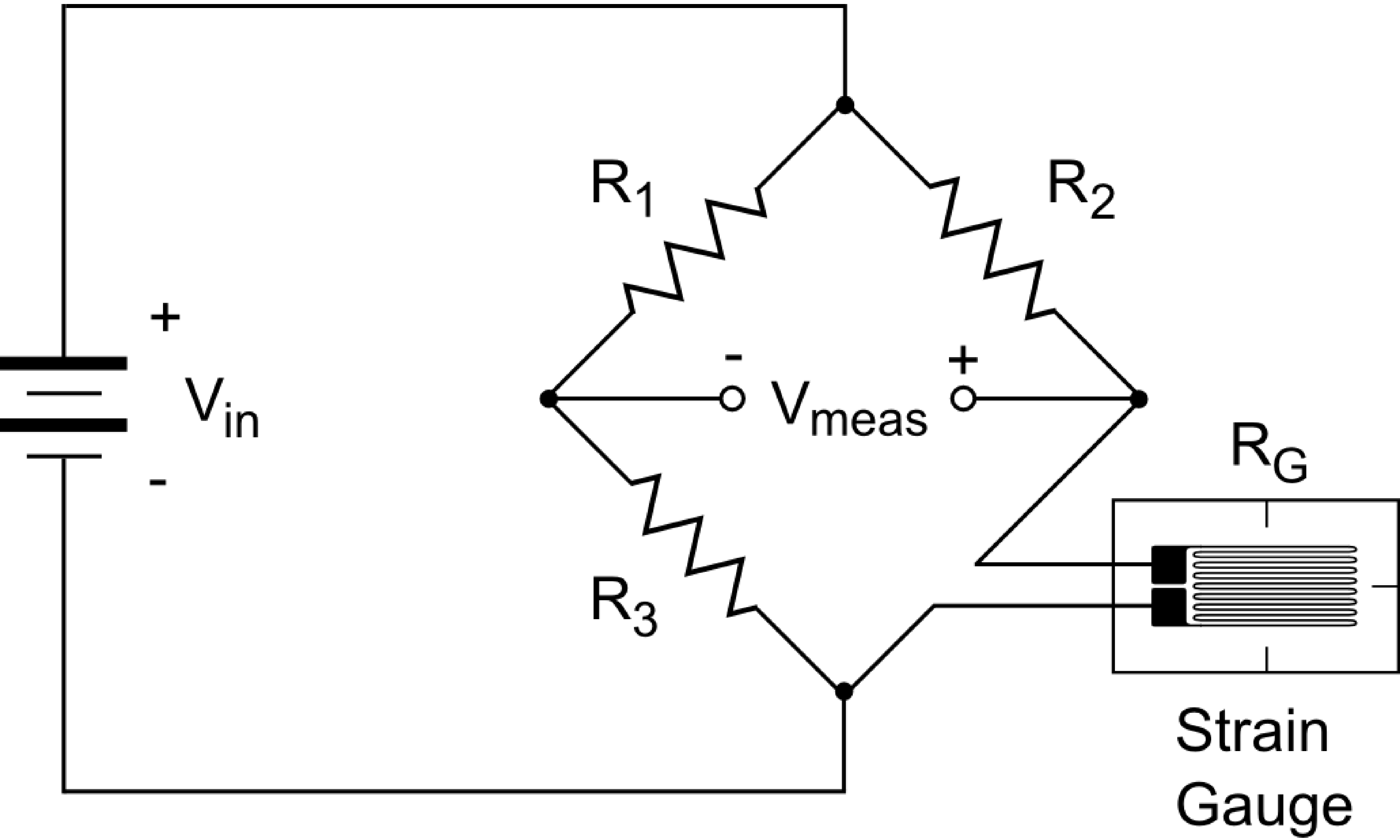


Figure 2.5 Isolation in a disposable blood-pressure sensor Disposable blood-pressure sensors are made of clear plastic so air bubbles are easily seen. Saline flows from an intravenous (IV) bag through the clear IV tubing and the sensor to the patient. This flushes blood out of the tip of the indwelling catheter to prevent clotting. A lever can open or close the flush valve. The silicon chip has a silicon diaphragm with a four-resistor Wheatstone bridge diffused into it. Its electrical connections are protected from the saline by a compliant silicone elastomer gel, which also provides electrical isolation. This prevents electric shock from the sensor to the patient and prevents destructive currents during defibrillation from the patient to the silicon chip.



R1
R2
+
-
Vin
-
+
Vmeas
RG
R3
Strain
Gauge

Watch video # 3

- **Disadvantages of extravascular measurement**

  - The frequency response of the catheter-sensor system is limited by the hydraulic properties of the system.

  - Creates time delay in detection of pressures when a pressure pulse is transmitted.

➢ Intravascular Sensors

- The sensor is placed at the tip of the catheter.

- Catheter-tip sensors have the advantage that the hydraulic connection via the catheter is eliminated (between the source of pressure and the sensor element).

    - Remember: The frequency response of the catheter–sensor system is limited by the hydraulic properties of the system.

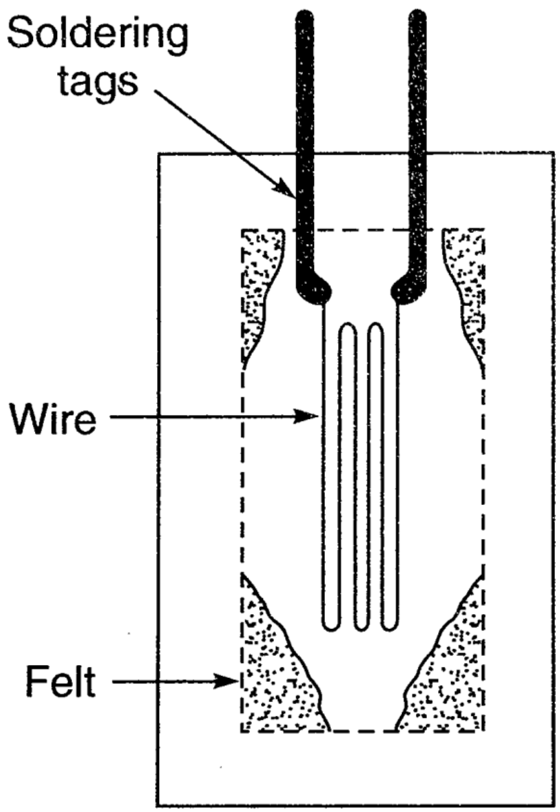
- Detection of pressures at the tip of the catheter without the use of a liquid-coupling system can thus enable the physician to obtain a high frequency response and eliminate the time delay encountered when the pressure pulse is transmitted in a catheter–sensor system.

→Types of used sensors

➢ Strain-gage pressure sensor

- bonded onto a flexible diaphragm at the catheter tip.

- Consists of strain-sensitive gages which are firmly bonded with an adhesive to the membrane or diaphragm whose movement is to be recorded.
- Made by taking a length of a very thin wire or foil which is formed into a grid pattern and bonded to a backing material.
- Is then attached to the diaphragm.
- Deflection of the diaphragm causes corresponding strain in the wire gage.
- Causes a corresponding change in the resistance which is proportional to the pressure.

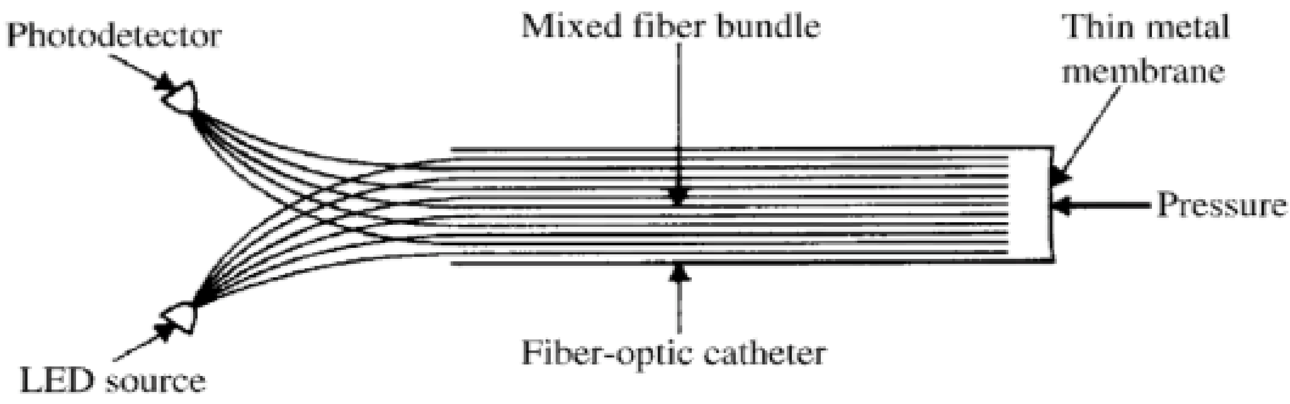


➢ fiber-optic pressure sensor

- Measures the displacement of the diaphragm optically by varying reflection of light from the back of the deflecting diaphragm.

- The fiber-optic intravascular pressure sensor can be made in sizes comparable to catheter-tip sensors, but at a lower cost.

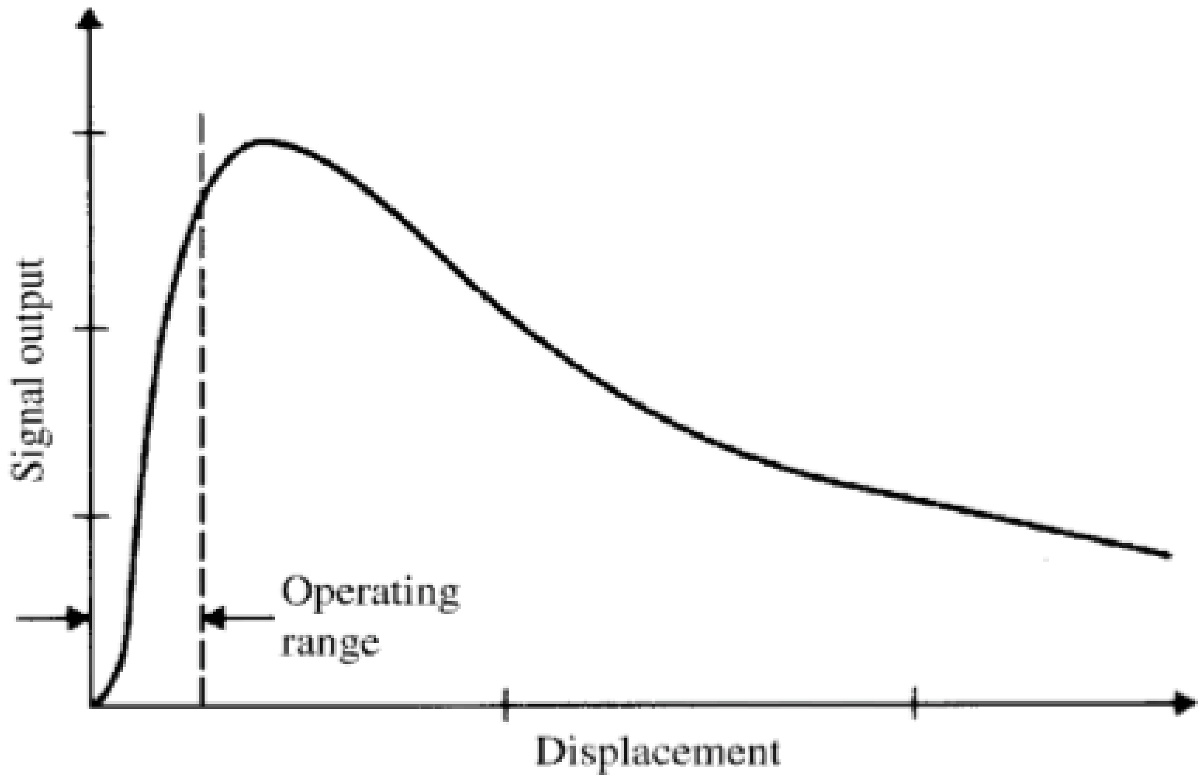
- A fiber-optic microtip sensor for *in vivo* measurements inside the human body is shown in Figure.



(a)

- one leg of a bifurcated fiber bundle is connected to a light-emitting diode (LED) source and the other to a photodetector. The pressure-sensor tip consists of a thin metal membrane mounted at the common end of the mixed fiber bundle.
- External pressure causes membrane deflection, varying the coupling between the LED source and the photodetector.

- Figure shows the output signal versus membrane deflection. Optical fibers have the property of emitting and accepting light within a cone defined by the acceptance angle θ_A



(b)

Example: intracranial pressure measurements in the newborn

- Device is applied to the anterior fontanel
- Pressure is applied with the sensor such that the curvature of the skin surface is flattened.
- When this applanation occurs, equal pressure exists on both sides of the membrane
- Pressure bends the membrane, which moves a reflector.
- This varies the amount of light coupling between the source and detector fibers.

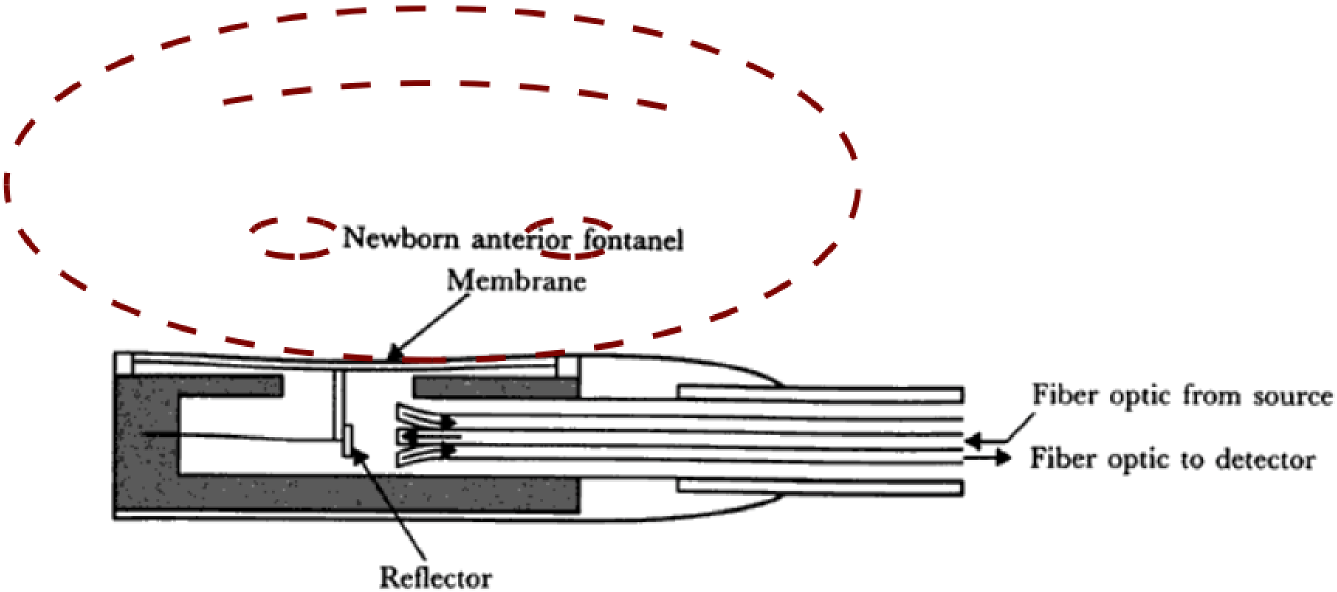


Figure 7.5 Fiber-optic pressure sensor for intracranial pressure measurements in the newborn. The sensor membrane is placed in contact with the anterior fontanel of the newborn.

Dynamic Properties of pressure-measurement systems

- An understanding of the dynamic properties of a pressure-measurement system is important if we wish to preserve the dynamic accuracy of the measured pressure.

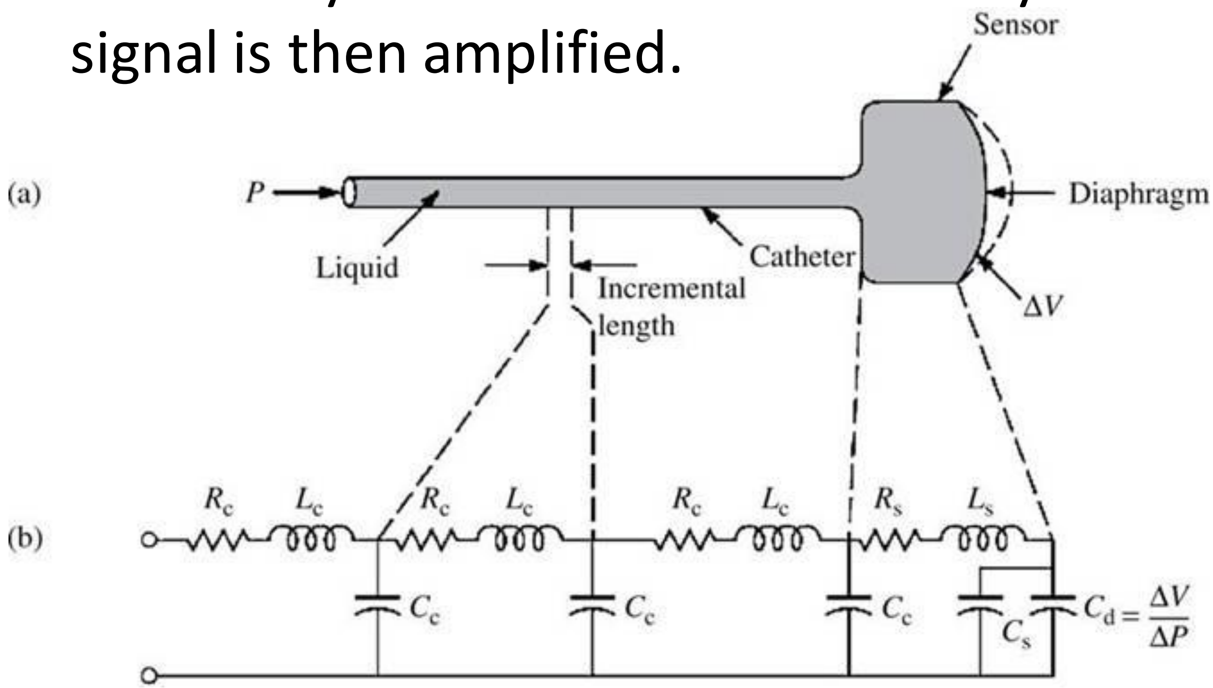
- Errors in measurement of dynamic pressure can have serious consequences in the clinical situation.

- Static characteristics: the performance criteria for the measurement of quantities that remain constant, or vary only quite slowly.

- Dynamic characteristics the relationship between the system input and output when the measured quantity (measurand) is varying rapidly.

➢ Analogous Electric Systems

- An increase in pressure at the input of the catheter causes a flow of liquid to the right from the catheter tip, through the catheter, and into the sensor.
- This liquid shift causes a deflection of the sensor diaphragm, which is sensed by an electromechanical system. The subsequent electric signal is then amplified.



(a) Physical model of a catheter-sensor system, (b) Analogous electric system for this catheter-sensor system. Each segment of the catheter has its own resistance R_c, inertance L_c, and compliance C_c. In addition, the sensor has resistance R_s, inertance, L_s, and compliance C_s. The compliance of the diaphragm is C_d.

3 components :(diaphragm, sensor and the liquid catheter)

Each component has :

Inertial :resistance to motion

Friction:touching other material

Compliance: Ability to change shape with pressure

- The liquid resistance R_c of the catheter :

$$R_c = \frac{\Delta P}{F} \left(\text{Pa} \cdot \text{s/m}^3\right) \text{ or } R_c = \frac{\Delta P}{\bar{u} A}$$

Poiseuille's equation

laminar or Poiseuille flow

$$R_c = \frac{8 \eta L}{\pi r^4}$$

p = pressure difference across the segment in Pa (pascal = N/m^2)

F = flow rate, m^3/s

$\bar{u}$ = average velocity, m/s

A = cross-section area, m^2

η = liquid viscosity

- we can **neglect the resistive components** of the sensor with respect to those of the liquid catheter, as the liquid-filled catheter is longer than the cavity of the sensor and of smaller diameter.

- The liquid inertance L_c of the catheter is due primarily to the mass of the liquid :

$$L_c = \frac{\Delta P}{dF/dt} \left(\mathrm{Pa \cdot s^2/m^3}\right) \quad \text{or} \quad L_c = \frac{\Delta P}{aA} \Longrightarrow L_c = \frac{m}{A^2} \quad \text{or} \quad L_c = \frac{\rho L}{\pi r^2}$$

a = acceleration; m/s^2

- we can **neglect the inertial components** of the sensor with respect to those of the liquid catheter, as the liquid-filled catheter is longer than the cavity of the sensor and of smaller diameter.

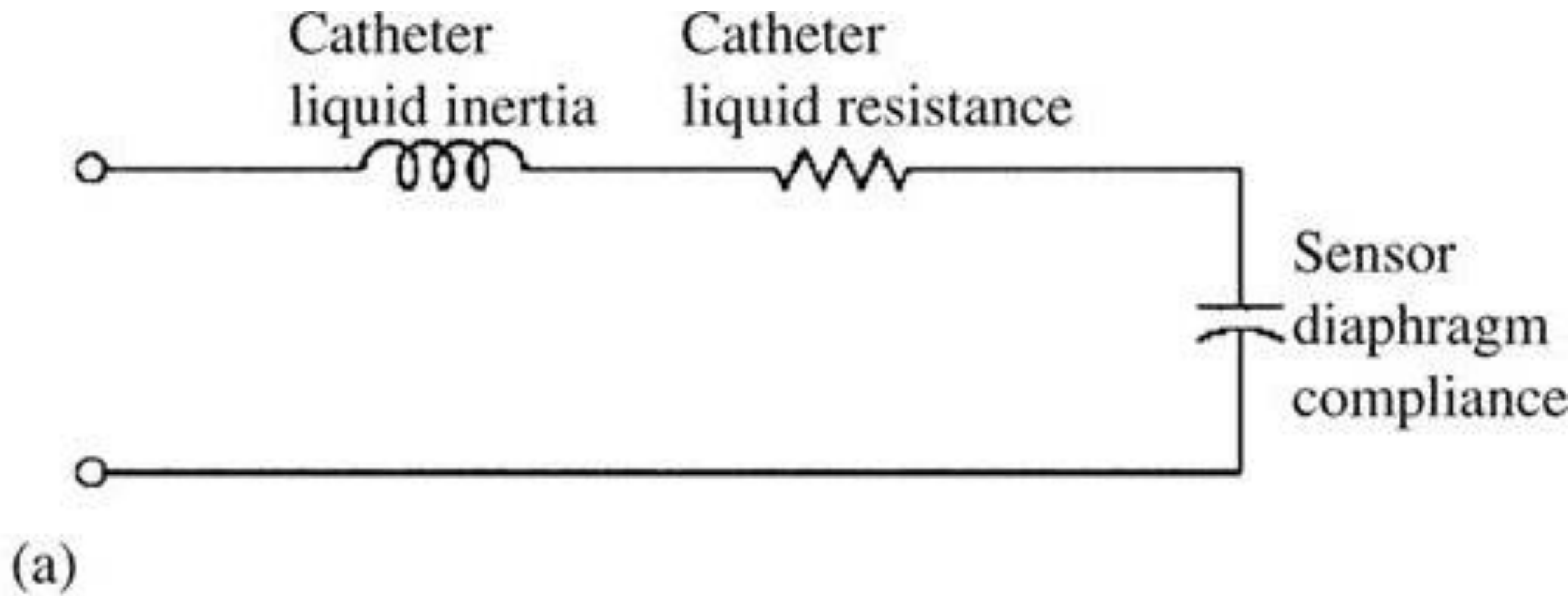
- The compliance C_d of the sensor diaphragm

$$C_{\mathrm{d}} = \frac{\Delta V}{\Delta P} = \frac{1}{E_{\mathrm{d}}}$$

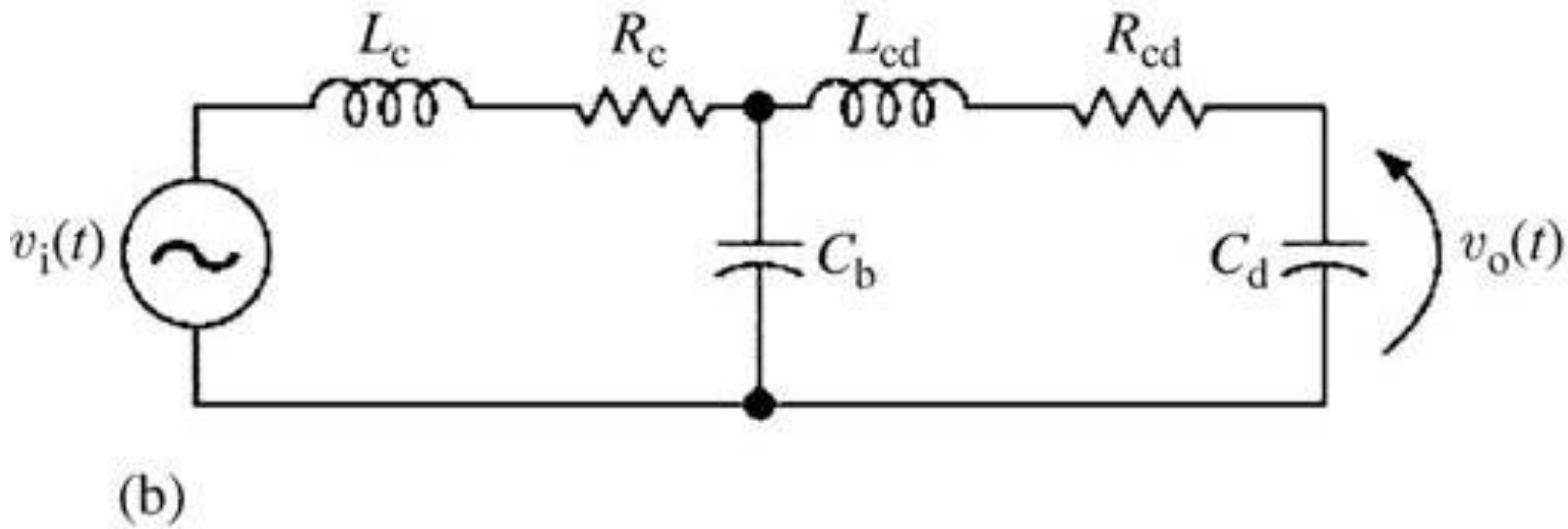
E_d is the volume modulus of elasticity of the sensor diaphragm

- compliance of the sensor diaphragm is much larger than that of the liquid-filled catheter or sensor cavity so <u>neglect the compliance of liquid-filled catheter</u>

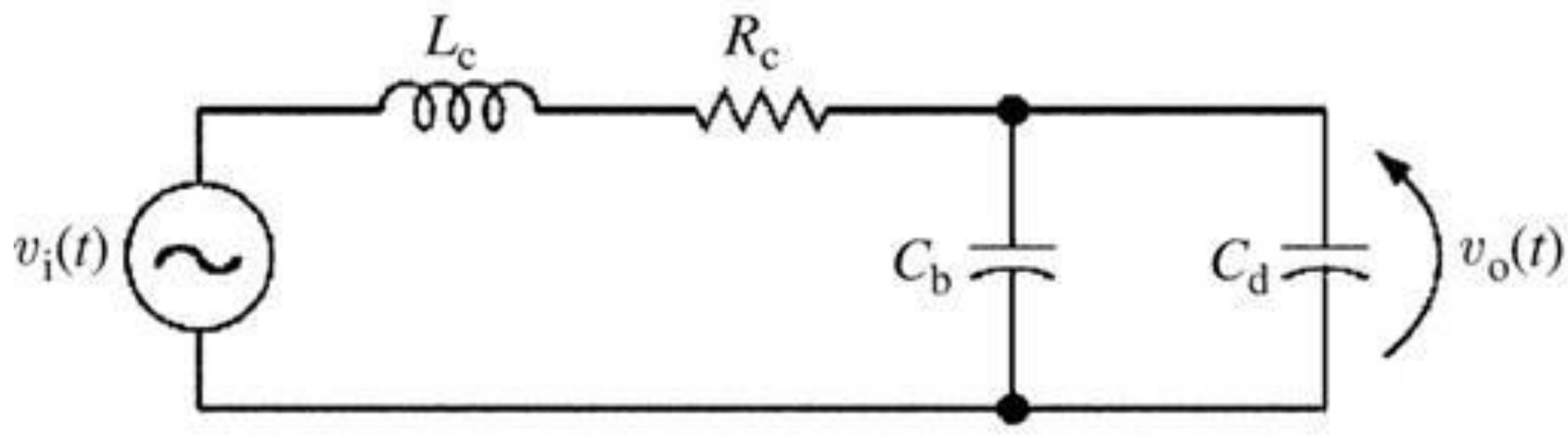
Simplified analogous circuit:



Compliance of the sensor diaphragm is larger than compliance of catheter or sensor cavity for a bubble-free, noncompliant catheter. The resistance and inertance of the catheter are larger than those of the sensor, because the catheter has longer length and smaller diameter



(b) Analogous circuit for catheter–sensor system with a bubble in the catheter. Catheter properties proximal to the bubble are inertance L_c and resistance R_c. Catheter properties distal to the bubble are L_{cd} and R_{cd}. Compliance of the diaphragm is C_d; compliance of the bubble is C_b.



(c)

(c) Simplified analogous circuit for catheter–sensor system with a bubble in the catheter, assuming that L_{cd} and R_{cd} are negligible with respect to R_c and L_c.

$$C_d = \frac{\Delta V}{\Delta P} = \frac{1}{E_d} \qquad C_t = \frac{\Delta V}{\Delta P_d} + \frac{\Delta V}{\Delta P_b}$$

- relationship between the input voltage V_i, analogous to applied pressure, and the output voltage V_o, analogous to pressure at the diaphragm, by using Kirchhoff's voltage law

$$v_{\mathrm{i}}(t) = \frac{L_{\mathrm{c}} C_{\mathrm{d}} d^2 v_{\mathrm{o}}(t)}{dt^2} + \frac{R_{\mathrm{c}} C_{\mathrm{d}} d v_{\mathrm{o}}(t)}{dt} + v_{\mathrm{o}}(t)$$

$$f_{\mathrm{n}} = \frac{r}{2}\left(\frac{1}{\pi \rho L}\,\frac{\Delta P}{\Delta V}\right)^{1/2}$$

Natural Frequency

$$\zeta = \frac{4\eta}{r^3}\left(\frac{L(\Delta V/\Delta P)}{\pi \rho}\right)^{1/2}$$

damping ratio

- We can study the transient response and the frequency response of the catheter–sensor system by means of the analogous electric circuit.

- we can study the effects of changes in the hydraulic system by adding appropriate elements to the circuit

EXAMPLE 7.1 A 5 mm-long air bubble has formed in the rigid-walled catheter connected to a Statham P23Dd sensor. The catheter is 1 m long, 6 French diameter, and filled with water at 20 °C. (The isothermal compression of air $\Delta V/\Delta P$ is 1 ml/cm of water pressure per liter of volume.) Plot the frequency-response curve of the system with and without the bubble. (Internal radius of the catheter is 0.46 mm; volume modulus of elasticity of the diaphragm is 0.49×10^{15} N/m^5.)

ANSWER

natural frequency f_n and the damping ratio ζ without the bubble

$$f_n = \frac{r}{2}\left(\frac{1}{\pi L}\frac{\Delta P}{\rho \Delta V}\right)^{1/2}$$

$$= \frac{0.046 \times 10^{-2}}{2}\left(\frac{1}{\pi(1)}\frac{0.49 \times 10^{15}}{1 \times 10^3}\right)^{1/2} = 91\ \text{Hz}$$

$$\zeta = \frac{4\eta}{r^3}\left(\frac{L}{\pi\rho}\frac{\Delta V}{\Delta P}\right)^{1/2}$$

$$= \frac{4(0.001)}{(0.046 \times 10^{-2})^3}\left(\frac{1}{\pi}\frac{1}{(1 \times 10^3)(0.49 \times 10^{15})}\right)^{1/2} = 0.033$$

The next step is to calculate the new values of ζ and f_n, for the case in which a bubble is present. Because the two capacitors are in parallel, the total capacitance for the circuit is equal to the sum of these two. That is,

$$C_t = C_d + C_b \tag{7.8}$$

or

$$C_t = \frac{\Delta V}{\Delta P_d} + \frac{\Delta V}{\Delta P_b}$$

The value of $\Delta V/\Delta P_d = 1/E_d = 2.04 \times 10^{-15}\,\mathrm{m^5/N}$. The volume of the bubble is

$$\pi r^2 l = 3.33 \times 10^{-9}\,\mathrm{m^3} = 3.33 \times 10^{-6}\,\text{liter}$$

One centimeter of water pressure is 98.5 N/m^2. Thus

$$\Delta V/\Delta P_b = \frac{3.33 \times 10^{-9} 1 \times (1 \times 10^{-3}\mathrm{m^3}/1)}{98.5\,\mathrm{N/m^2}} = 3.38 \times 10^{-14}\,\mathrm{m^5/N}$$

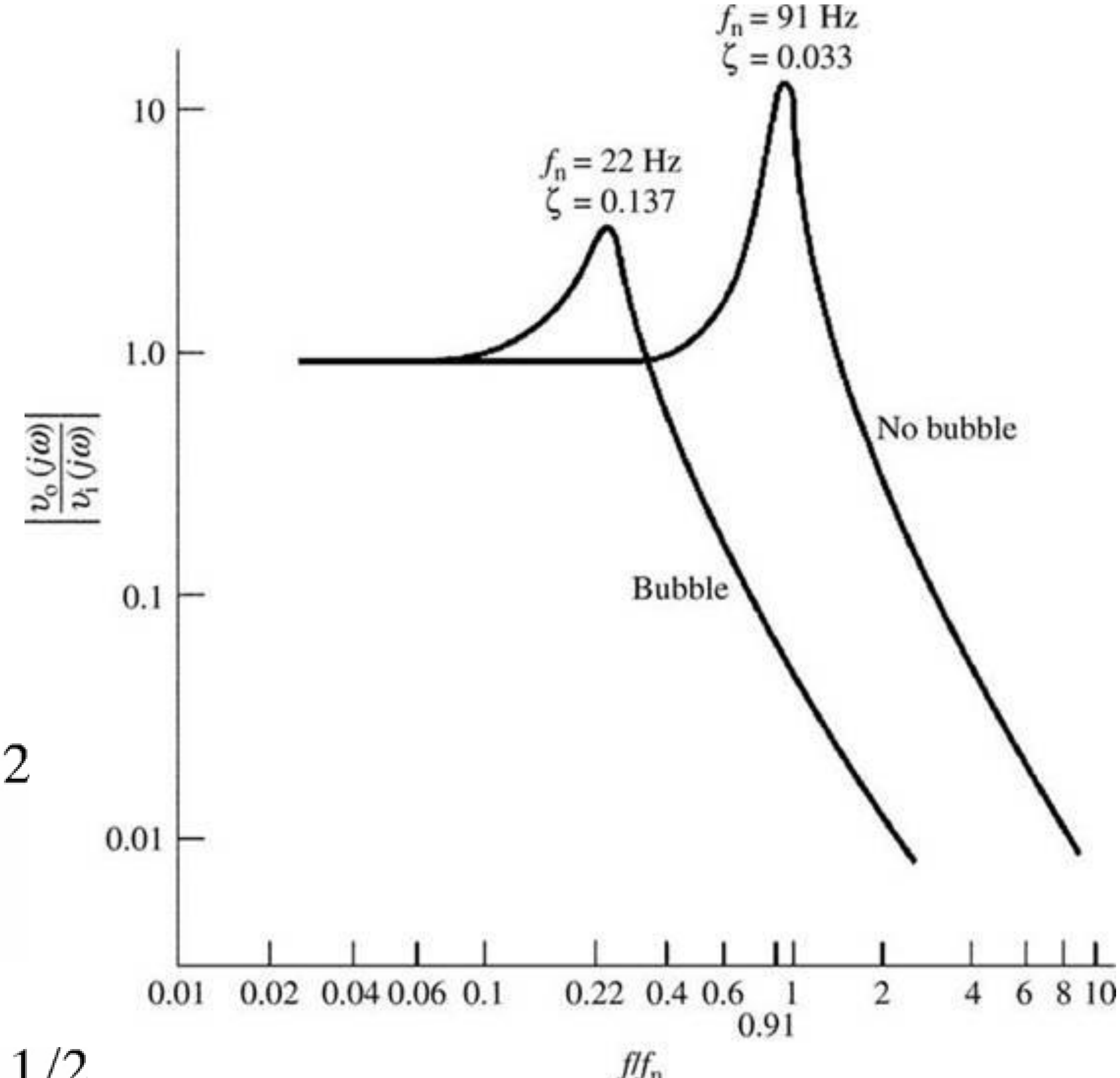
Consequently, $C_t = 3.38 \times 10^{-14}\,\mathrm{m^5/N}$.

$$f_{n,\,\text{bubble}} = f_{n,\,\text{no bubble}} \left(\frac{\Delta P \Delta V_{\text{total}}}{\Delta P/\Delta V_{\text{no bubble}}} \right)^{1/2} \longrightarrow f_{n,\,\text{bubble}} = 92 \left(\frac{2.04 \times 10^{-15}}{3.38 \times 10^{-14}} \right)^{1/2} = 22\,\mathrm{Hz}$$

$$\zeta_{\text{bubble}} = \zeta_{\text{no bubble}} \left(\frac{\Delta V/\Delta P_{\text{total}}}{\Delta V/\Delta P_{\text{no bubble}}} \right)^{1/2} = 0.137$$

$$f_n = \frac{r}{2}\left(\frac{1}{\pi\rho L}\frac{\Delta P}{\Delta V}\right)^{1/2}$$

$$\zeta = \frac{4\eta}{r^3}\left(\frac{L(\Delta V/\Delta P)}{\pi\rho}\right)^{1/2}$$



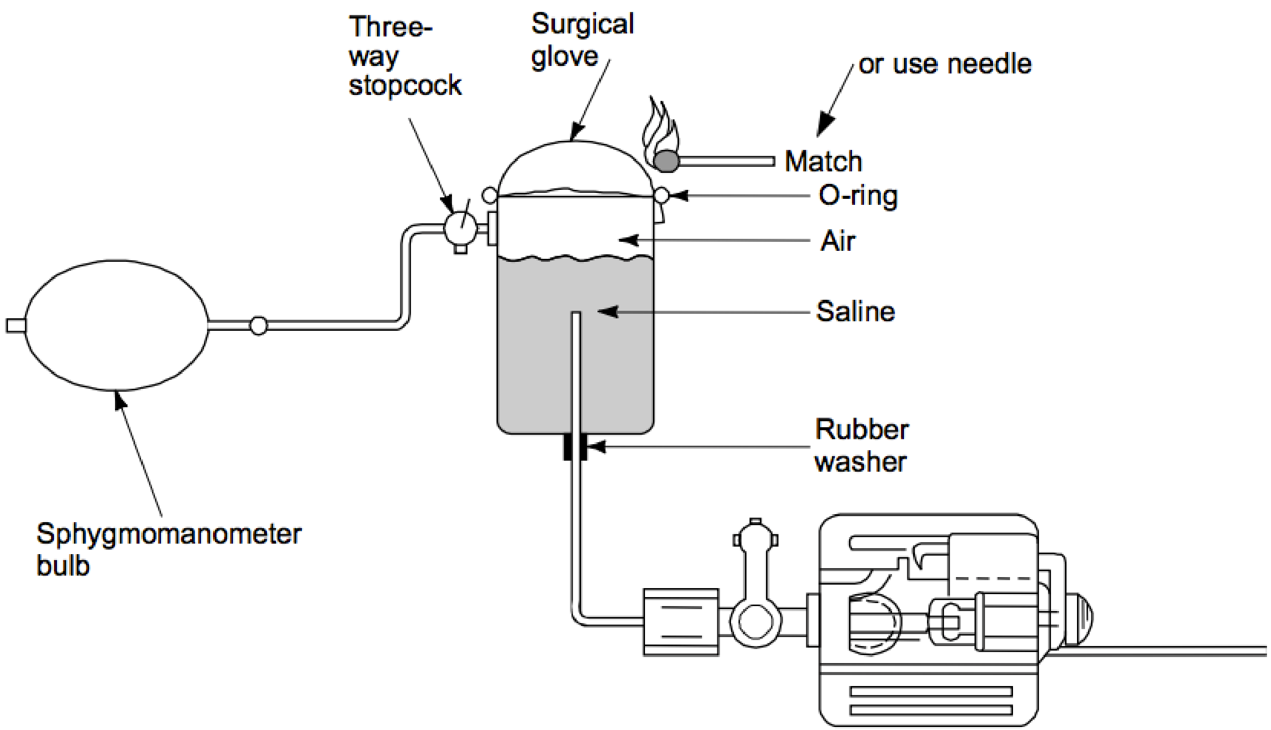
Frequency-response curves for catheter–sensor system with and without bubbles. Natural frequency decreases from 91 Hz to 22 Hz and damping ratio increases from 0.033 to 0.137 with the bubble present.

➢ Measurement of System Response

- The response characteristics of a catheter–sensor system can be determined by two methods.

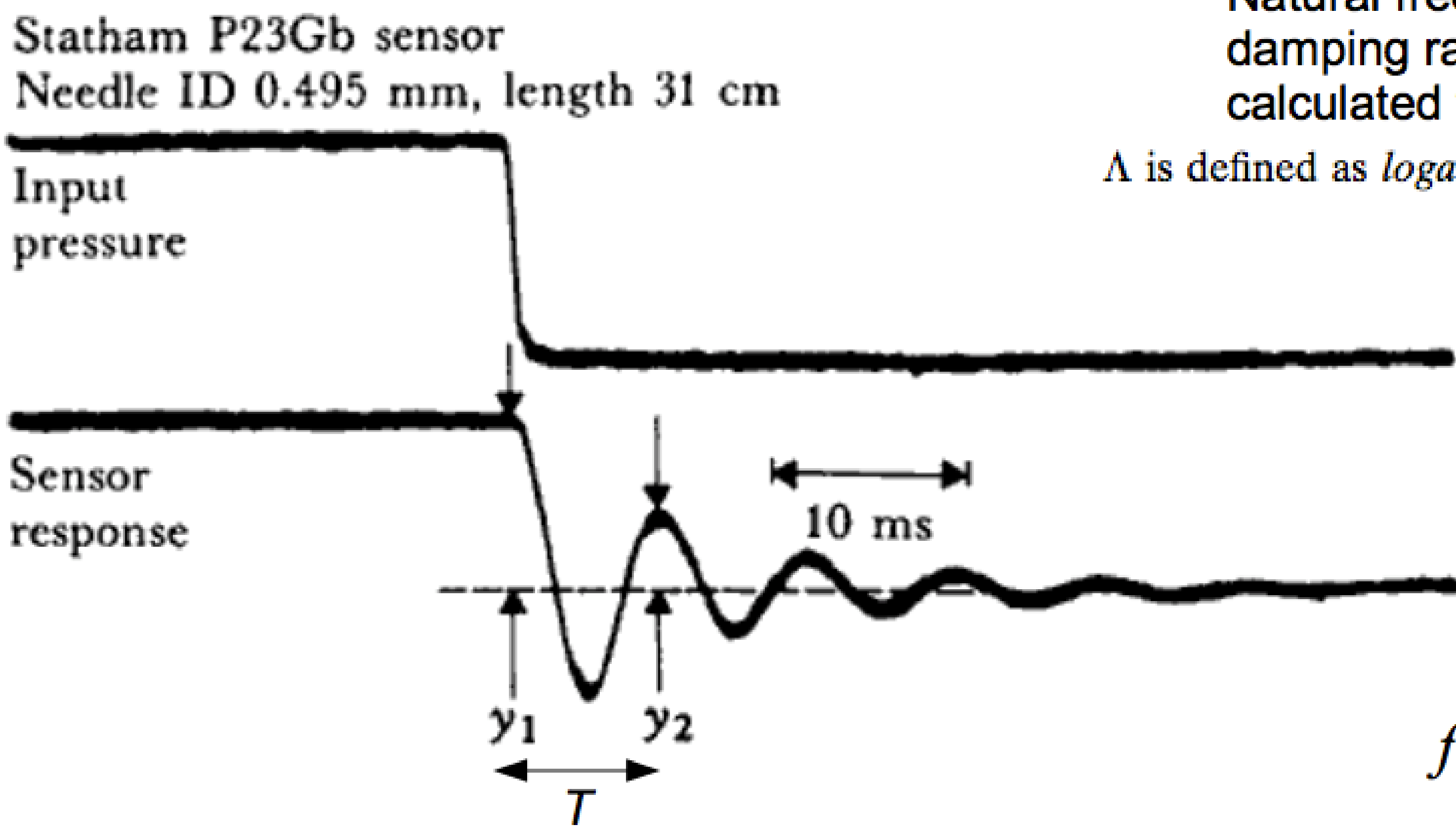
1. Transient Step Response

- The basis of the transient-response method is to apply a sudden step input to the pressure catheter and record the resultant damped oscillations of the system. This technique is also called as pop technique.



Transient-response technique for testing a pressure-sensor-catheter-sensor system.

Pressure-sensor transient response



Natural frequency and damping ratio can be calculated from the curve

Λ is defined as *logarithmic decrement*.

$$\Lambda = \frac{y_n}{y_{n+1}}$$

$$\zeta = \frac{\Lambda}{\sqrt{4\pi^2 + \Lambda^2}}$$

$$f_n = \frac{1}{T\sqrt{1-\zeta^2}}$$

Pressure-sensor transient response Negative-step input pressure is recorded on the top channel; the bottom channel is sensor response for a Statham P23Gb sensor connected to a 31-cm needle (0.495 mm ID). (Gabe, 1972.)

2. Sinusoidal Frequency Response

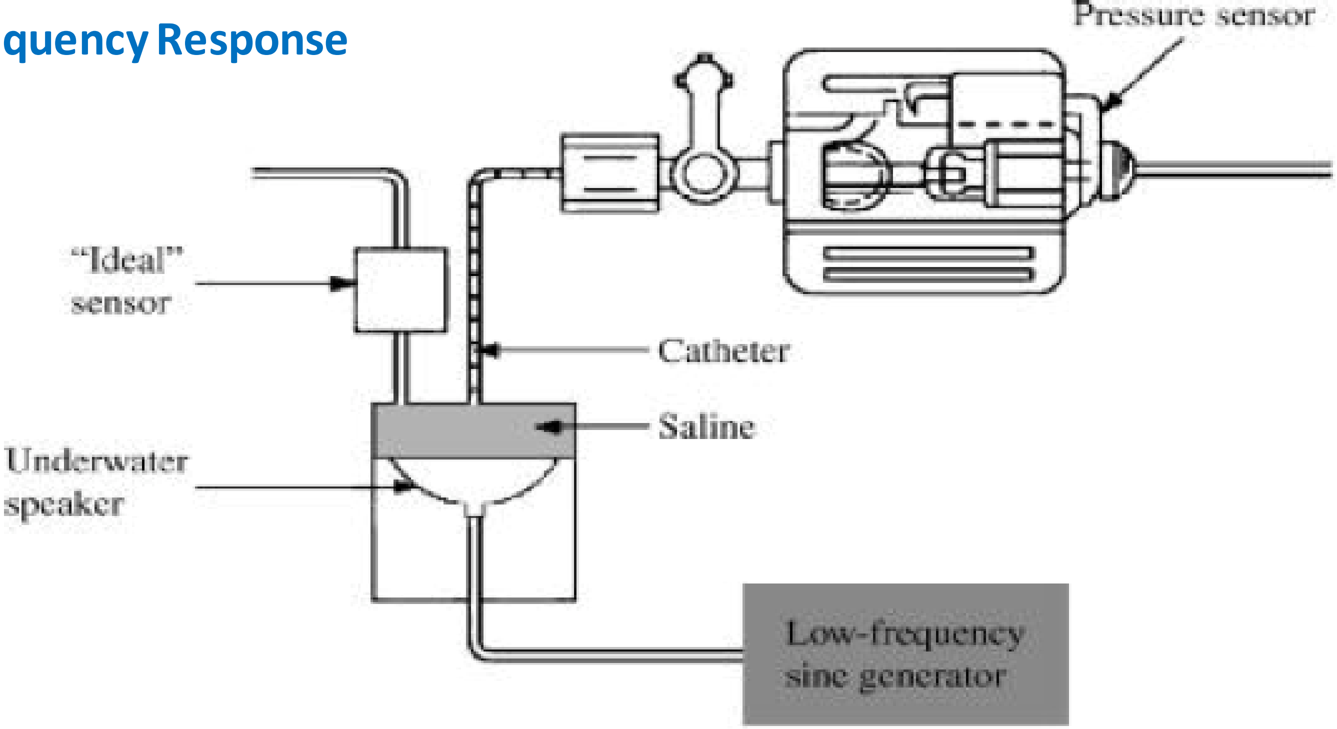


Figure 7.12 A sinusoidal pressure-generator test system A low-frequency sine generator drives an underwater-speaker system that is coupled to the catheter of the pressure sensor under test. An "ideal" pressure sensor, with a frequency response from 0 to 100 Hz, is connected directly to the test chamber housing and monitors input pressure.

- A pump produces sinusoidal pressures that are normally monitored at the pressure source by a pressure sensor with known characteristics. This is used because the amplitudes of the source-pressure waveforms are not normally constant for all frequencies.
- The source pressure is coupled to the catheter sensor under test by means of bubble-free saline. The air is removed by boiling the liquid.

Pressure-Waveform Distortion

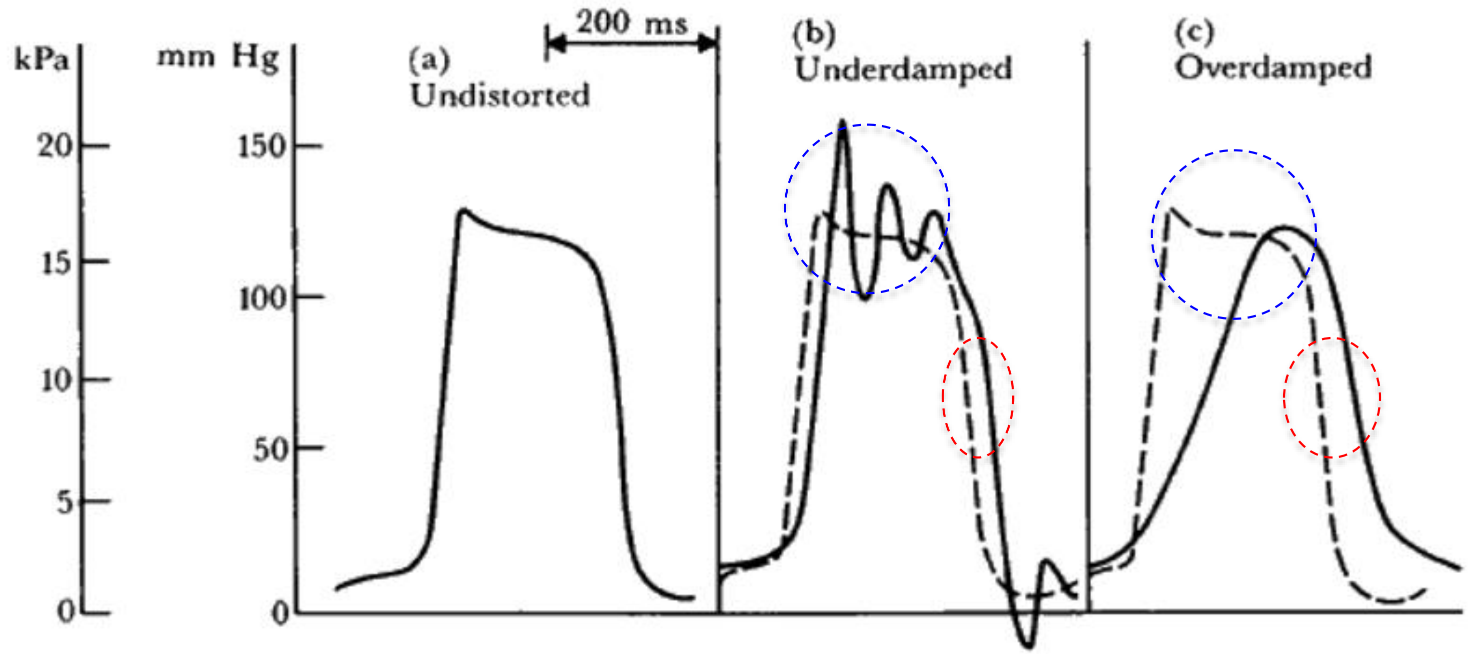


Figure 7.13 Pressure-waveform distortion (a) Recording of an undistorted left-ventricular pressure waveform via a pressure sensor with bandwidth dc to 100 Hz.

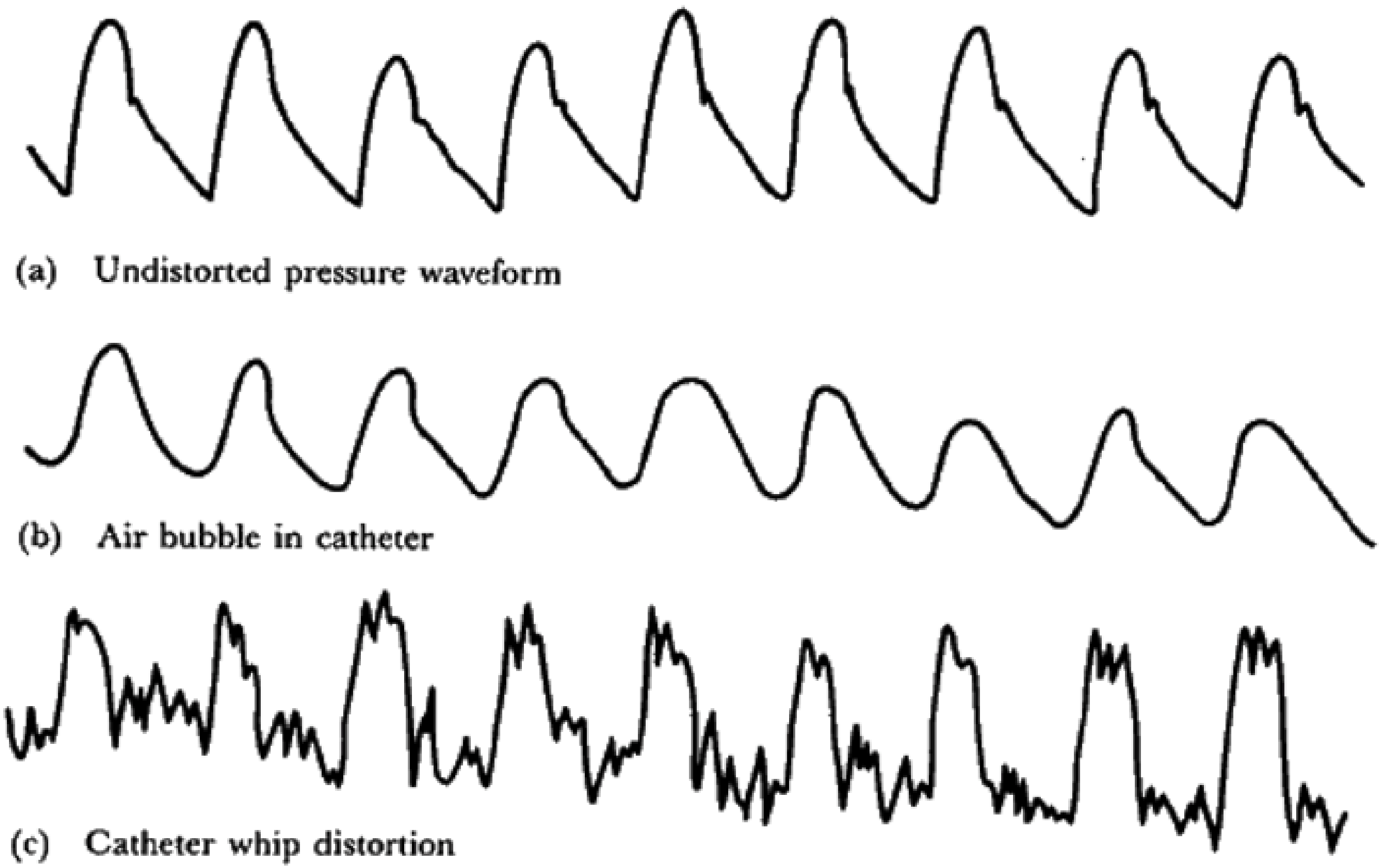
(a) Recording of an undistorted left-ventricular pressure waveform via a pressure sensor with bandwidth dc to 100 Hz. Actual peak :130 mm Hg (17.2 kPa).

(b) Underdamped response, where peak value is increased. A time delay is also evident in this recording. Peak value: 165 mm Hg (22 kPa), time delay: ~ 30 ms

(c) Overdamped response that shows a significant time delay and an attenuated amplitude response. . Peak value: 120 mm Hg (16 kPa), time delay: ~ 150 ms

Effect of Distortion in Catheter Measurements

Low frequency oscillations that appear in blood-pressure recording.



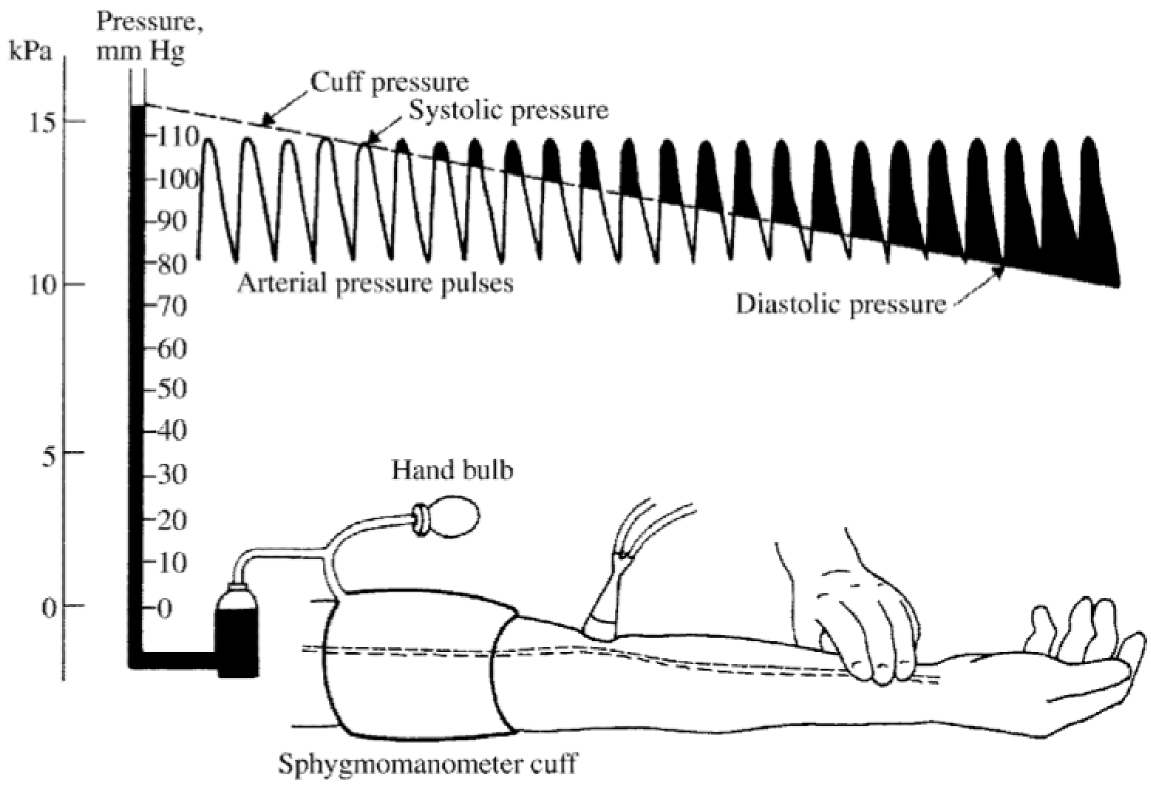
Distortion during the recording of arterial pressure. The bottom trace is the response when the pressure catheter is bent and whipped by accelerating blood in regions of high pulsatile flow.

② **Non Invasive (Indirect) Method**

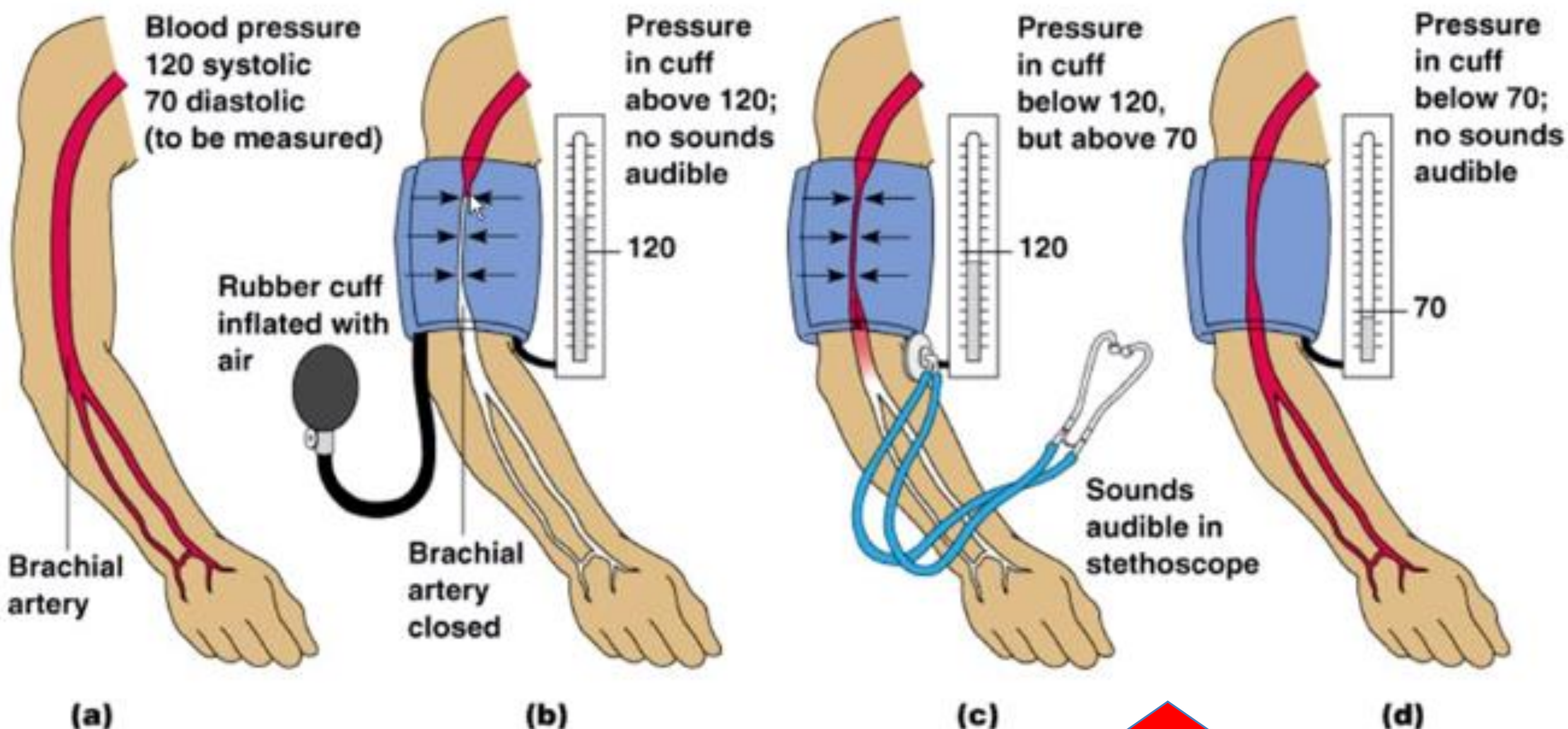
- Indirect measurement of blood pressure is an attempt to measure intra-arterial pressures noninvasively.

❑ Sphygmomanometer

- The sphygmomanometer cuff is inflated by a hand bulb to pressure above the systolic level (look at Figure).
- Pressure is then slowly released, and blood flow under the cuff is monitored by a microphone or stethoscope placed over a downstream artery.
- The first Korotkoff sound detected indicated systolic pressure, whereas the transition from muffling to silence brackets diastolic pressure

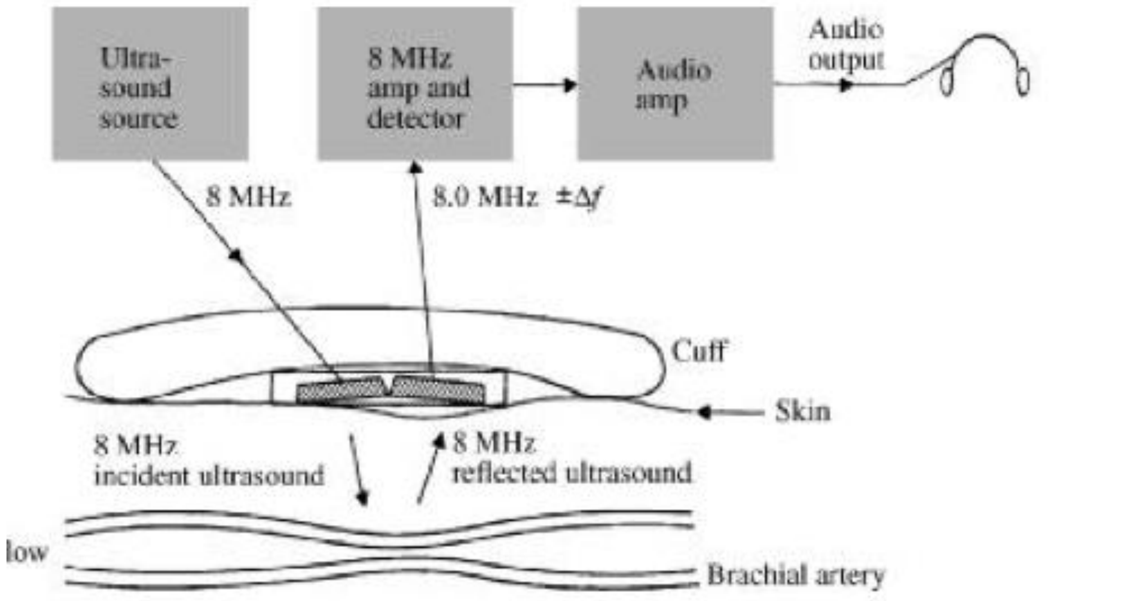


(From R.F. Rushmer, Cardiovascular Dynamics, 3rd ed., 1970. Philadelphia: W.B. Saunders Co. Used with permission.)



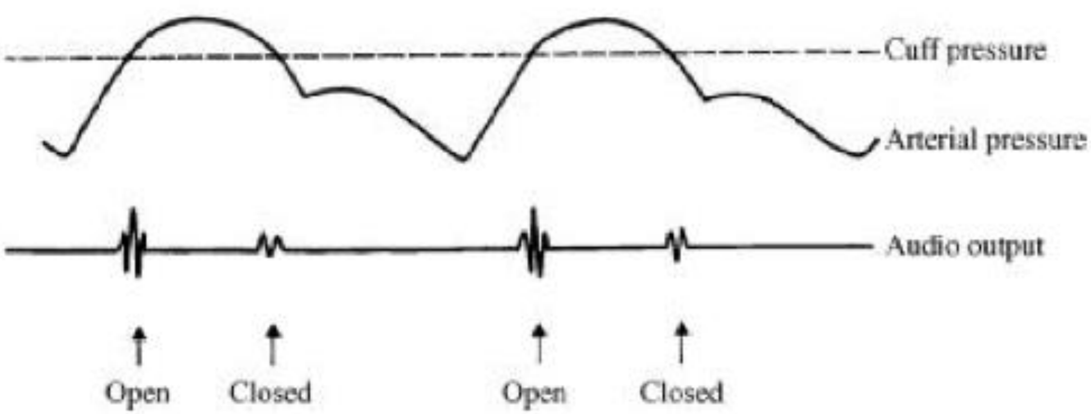
Watch video
11-2

❑ Ultrasonic Determination of Blood Pressure



Ultrasonic determination of blood pressure

- A compression cuff is placed over the transmitting (8 MHz) and receiving (8 MHz ± Δf) crystals.
- The opening and closing of the blood vessel are detected as the applied cuff pressure is varied.



Watch video doppler

The advantages of the ultrasonic technique are that it can be used with infants and hypotensive individuals and in high-noise environments. A disadvantage is that movements of the subject’s body cause changes in the ultrasonic path between the sensor and the blood vessel.

❑ Oscillometric detection of blood pressure

- The oscillometric method, a noninvasive blood pressure technique, measures the amplitude of oscillations that appear in the cuff pressure signal which are created by expansion of the arterial wall each time blood is forced through the artery.

- The cuff-pressure signal increases in strength in the systolic pressure region, reaching a maximum when the cuff pressure is equal to mean arterial pressure.

- As the cuff pressure drops below this point, the signal strength decreases proportionally to the cuff air pressure bled rate.

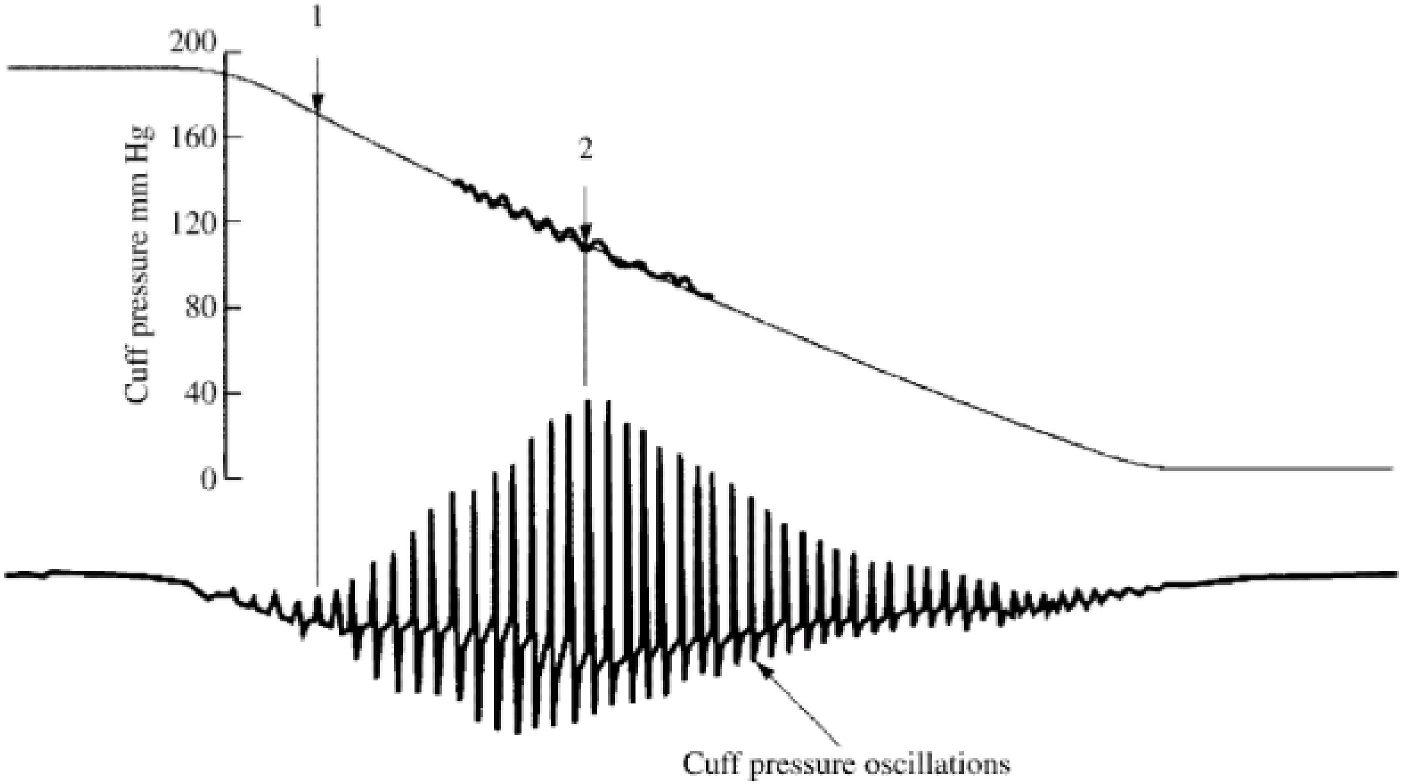
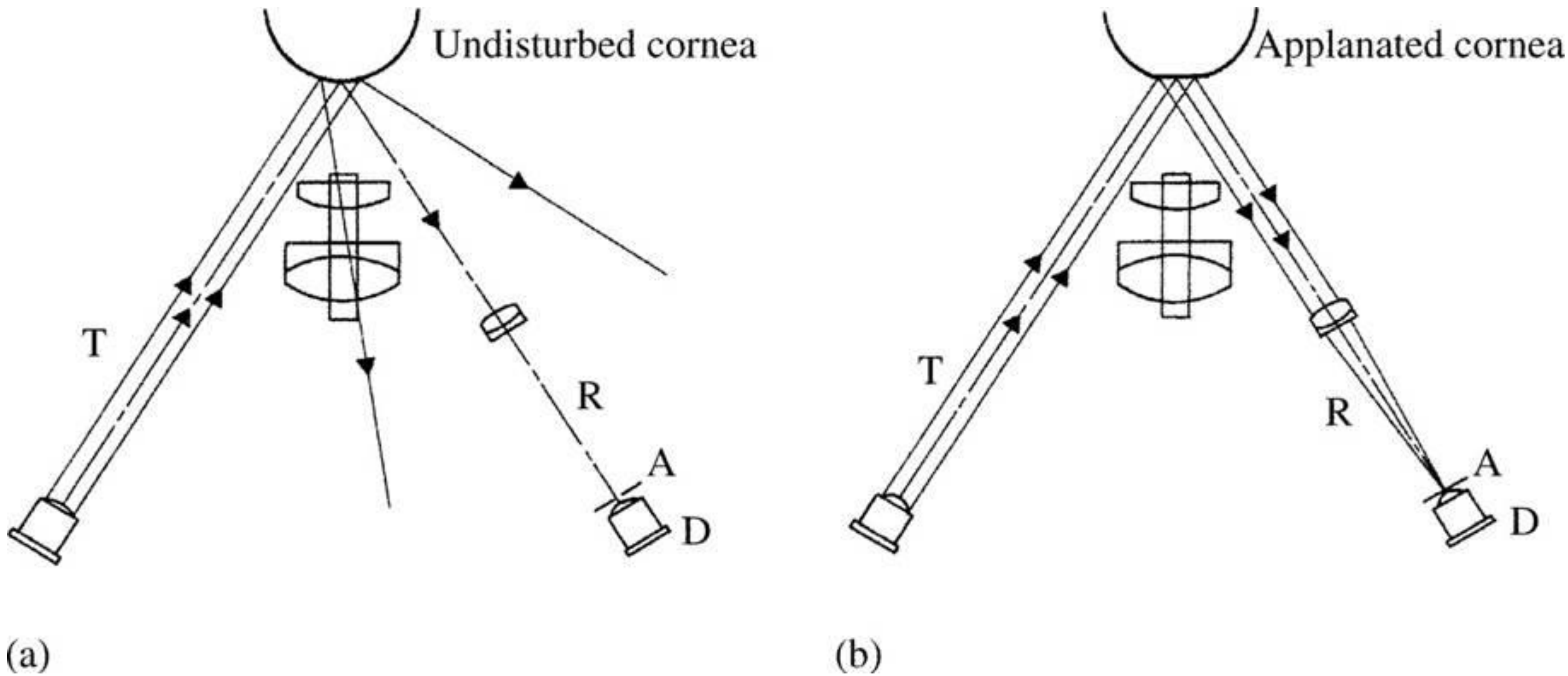


Figure 7.22 The oscillometric method A compression cuff is inflated above systolic pressure and slowly deflated. Systolic pressure is detected (point 1) where there is a transition from small amplitude oscillations (above systolic pressure) to increasing cuff-pressure amplitude. The cuff-pressure oscillations increase to a maximum (point 2) at the mean arterial pressure.

- Easy to obtain systolic and MABP, however, there is no clear indication of the diastolic pressure. Proprietary algorithms are used, instead

❑ Tonometer

- The basic principle of tonometry is that, when a pressurized vessel is partly collapsed by an external object, the circumferential stresses in the vessel wall are removed and the internal and external pressures are equal. This approach has been used quite successfully to measure intraocular pressure and has been used with limited success to determine intraluminal arterial pressure.



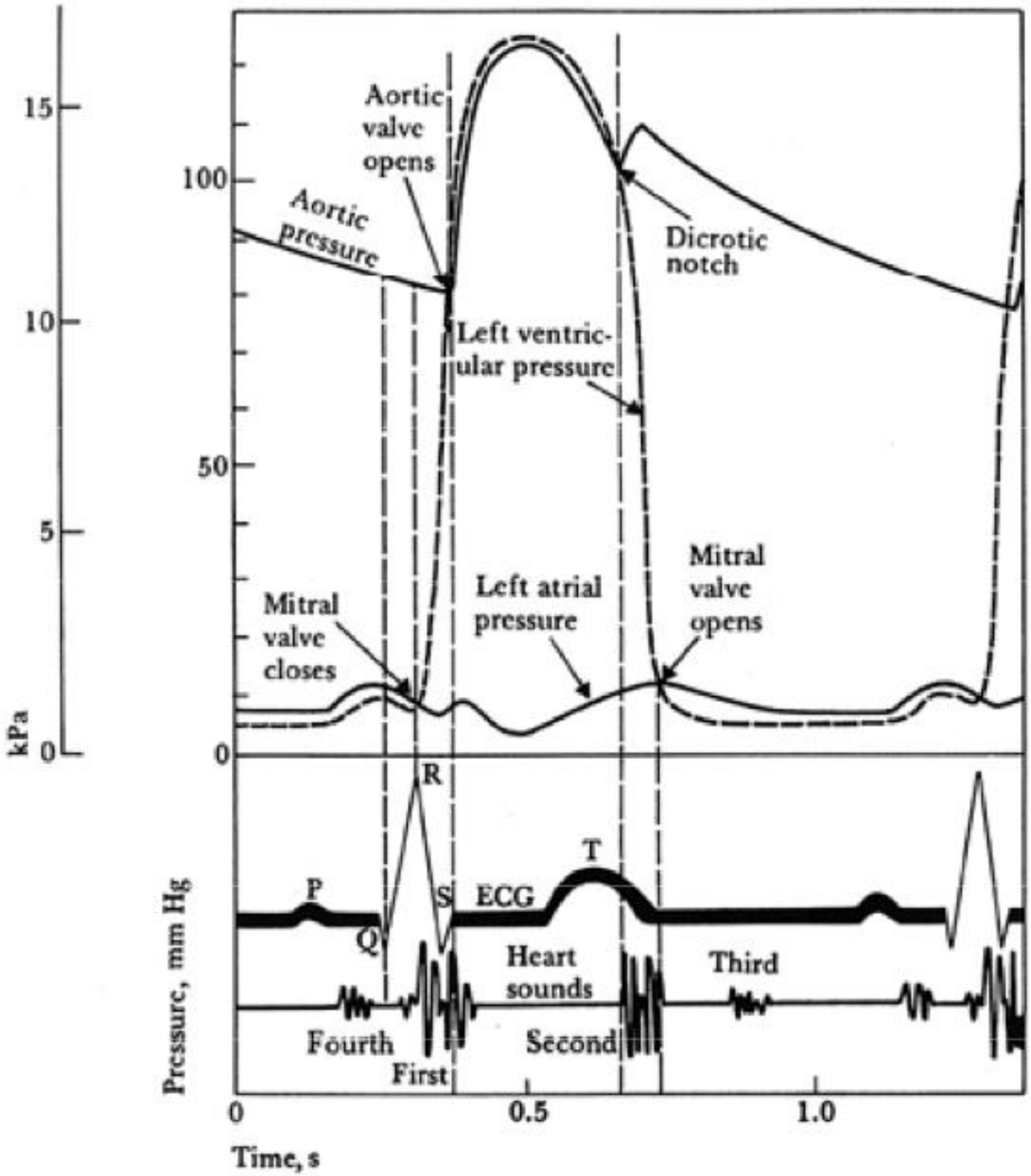
Monitoring system for noncontact applanation tonometer (From M. Forbes, G. Pico, Jr., and B. Grolman, "A Noncontact Applanation Tonometer, Description and Clinical Evaluation," *J. Arch. Ophthalmology*, 1975, 91, 134–140. Copyright © 1975, American Medical Association. Used with permission.)

HEART SOUND

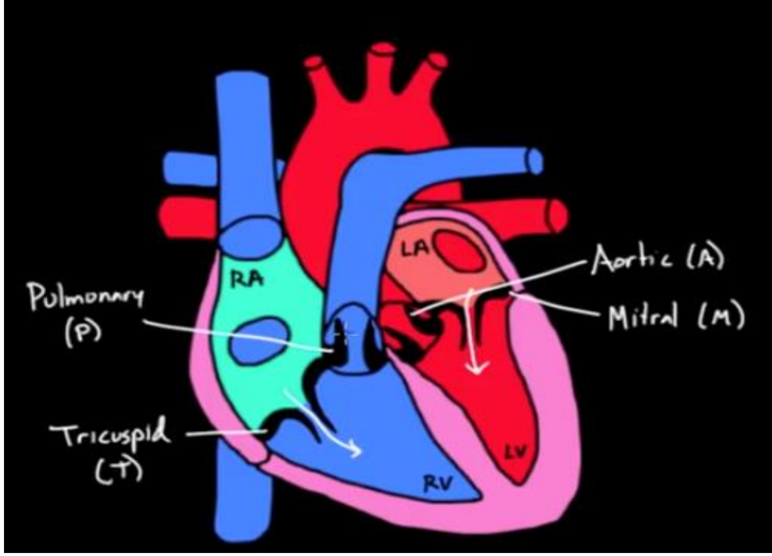
- The auscultation of the heart gives valuable information about the functional integrity of the heart. More information becomes available when clinicians compare the temporal relationships between the hearth sounds and the mechanical and electrical events of the cardiac cycle. This latter approach known as *phonocardiography*.

- Hearth sounds are vibrations or sounds due to the acceleration or deceleration of blood.

- Murmurs are vibrations or sounds due to the blood turbulence.



Correlation of the four hearth sounds with mechanical and electrical events of the cardiac cycle.



Hearth Sounds:

1st: Asynchronous closure of the tricuspid and mitral valves.

2nd:Closure of the semilunar valves (aortic and pulmonary valves) (end of the T wave of ECG)

3rd: End of ventricular filling. (Sudden termination of rapid filling phase of ventricles from atria and the associated vibration of ventricular muscle walls, which are relaxed)- audible in children and some adults

4th:Contraction of the atria and propelling blood into the ventricles - not audible

Normal/Abnormalities

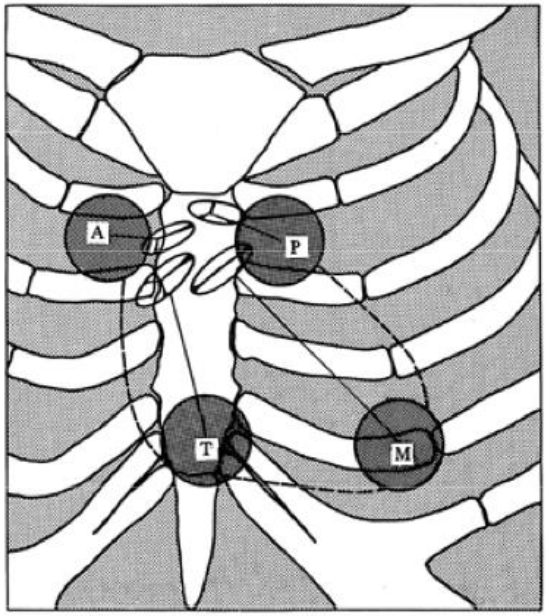
- The sources of most murmurs, developed by turbulence in rapidly moving blood, are known.
- Murmurs during the early systolic phase are common in children, and they are normally heard in nearly all adults after exercise.
- Abnormal murmurs may be caused by stenosis and insufficiencies (leaks) at the aortic, pulmonary, and mitral valves.
- They are detected by noting the time of their occurrence in the cardiac cycle and their location at the time of measurement.

Watch video # 6-1

Watch video # 6-2

Auscultation Techniques

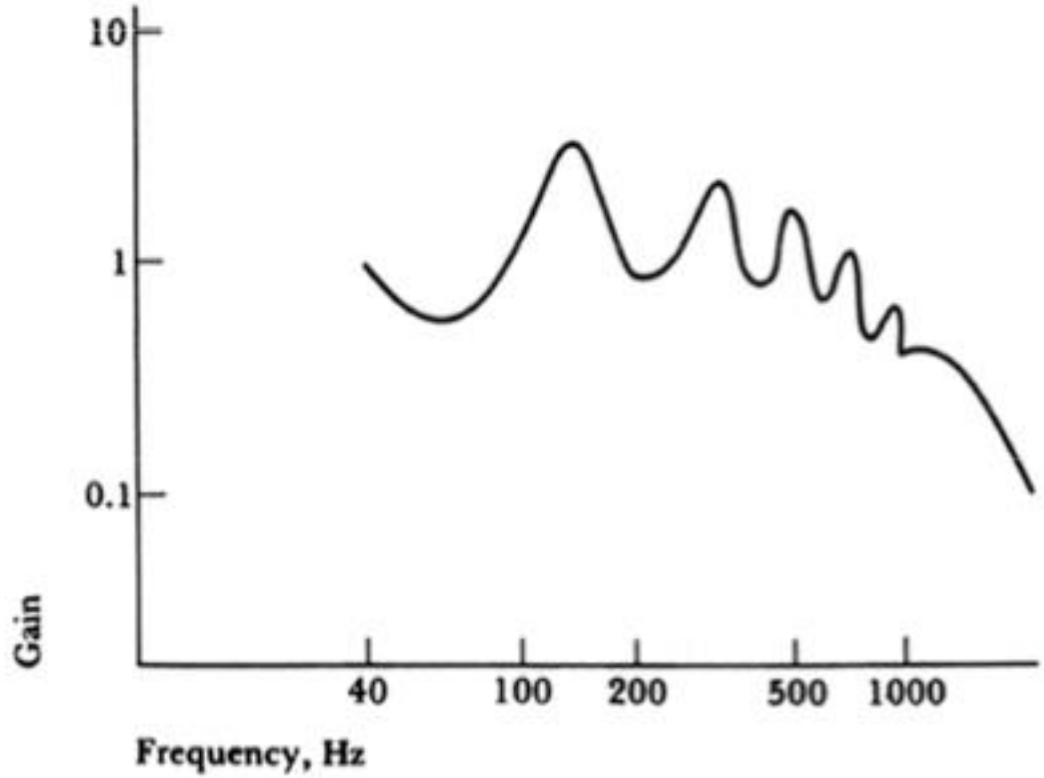
- Heart sounds travel through the body from the heart and major blood vessels to the body surface.
- Because of the acoustical properties of the transmission path, sound waves are attenuated and not reflected.
- The largest attenuation of the wavelike motion occurs in the most compressible tissues, such as the lungs and fat layers.



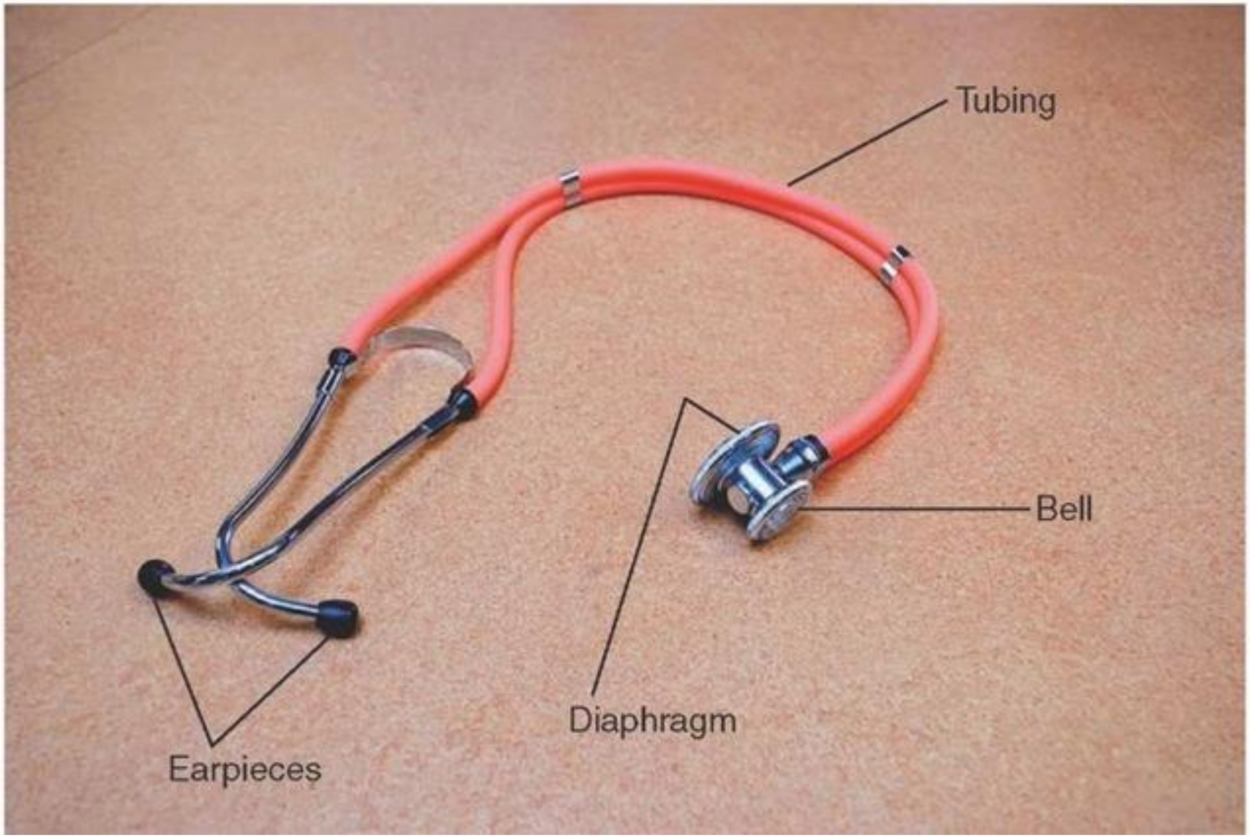
Auscultatory areas on the chest: A-aortic; P-pulmonary; T-tricuspid; M-mitral areas

Stethoscopes

- Stethoscopes are used to transmit hearth sounds from the chest wall to the human ear.
- The technique used to apply the stethoscope can greatly affect the sounds perceived.



- The typical frequency-response curve for a stethoscope can be found by applying a known audio-frequency signal to the bell of a stethoscope by means of a headphone-coupler arrangement.



http://what-when-how.com/paramedic-care/physical-examination-and-secondary-assessment-principles-of-clinical-practice-paramedic-care-part-1/

- Today, mechanical and electronic stethoscopes are in use.
- When stethoscope is placed on the patient, the vibrations of the skin directly produce acoustic pressure waves

Cardiac Characterization

- The cardiac-catheterization procedure is a combination of several techniques that are used to assess hemodynamic function and cardiovascular structure.

- Cardiac catheterization is performed in virtually all patients in whom heart surgery is contemplated. This procedure yields information that may be crucial in defining the timing, risks, and anticipated benefit for a given patient.

- Catheterization procedures are performed in specialized laboratories outfitted with x-ray equipment for visualizing heart structures and the position of various pressure catheters.

- Cardiac output is valuable for assessing the pumping function of the heart and can also be measured using dye dilution, the Fick method, and impedance cardiography

- Blood samples can be drawn from within the various heart chambers and vessels where the catheter tip is positioned. These blood samples are important in determining the presence of shunts between the heart chambers or great vessels.

  - For example, a shunt from the left to the right side of the heart is indicated by a higher-than-normal O_2 content in the blood in the right heart in the vicinity of the shunt.

- Cardiac blood samples are also used to assess such metabolic end products as lactate, pyruvate, CO2, and such injected substances as radioactive materials and colored dyes.

- Angiographic visualization is an essential tool used to evaluate cardiac structure. Radiopaque dye is injected rapidly into a cardiac chamber or blood vessel, and the hemodynamics are viewed and recorded on x-ray film, movie film, or videotape.
- Standard angiographic techniques are employed, where indicated, in the evaluation of the left and right ventricles (ventriculography), the coronary arteries (coronary arteriography), the pulmonary artery (pulmonary angiography) and the aorta (aortography).

- Clinicians can measure pressures in all four chambers of the heart and in the great vessels by positioning catheters, during **fluoroscopy**, in such a way that they can recognize the characteristic pressure waveforms. They measure pressures across the four valves to determine the valves' pressure gradients.

- An intravascular coronary ultrasound (IVUS), a tiny ultrasound ''camera'' on the tip of a coronary catheter, can be threaded into the coronary arteries to provide a cross-sectional view from the inside out. These IVUS pictures allow the clinician to determine the location and characteristics of the plaque.

- The percutaneous translumenal coronary angioplasty (PTCA) catheter is used to enlarge the lumen of stenotic coronary arteries, thereby improving distal flow and relieving symptoms of ischemia and signs of myocardial hypoperfusion.

Watch video # 8

Watch video # 9

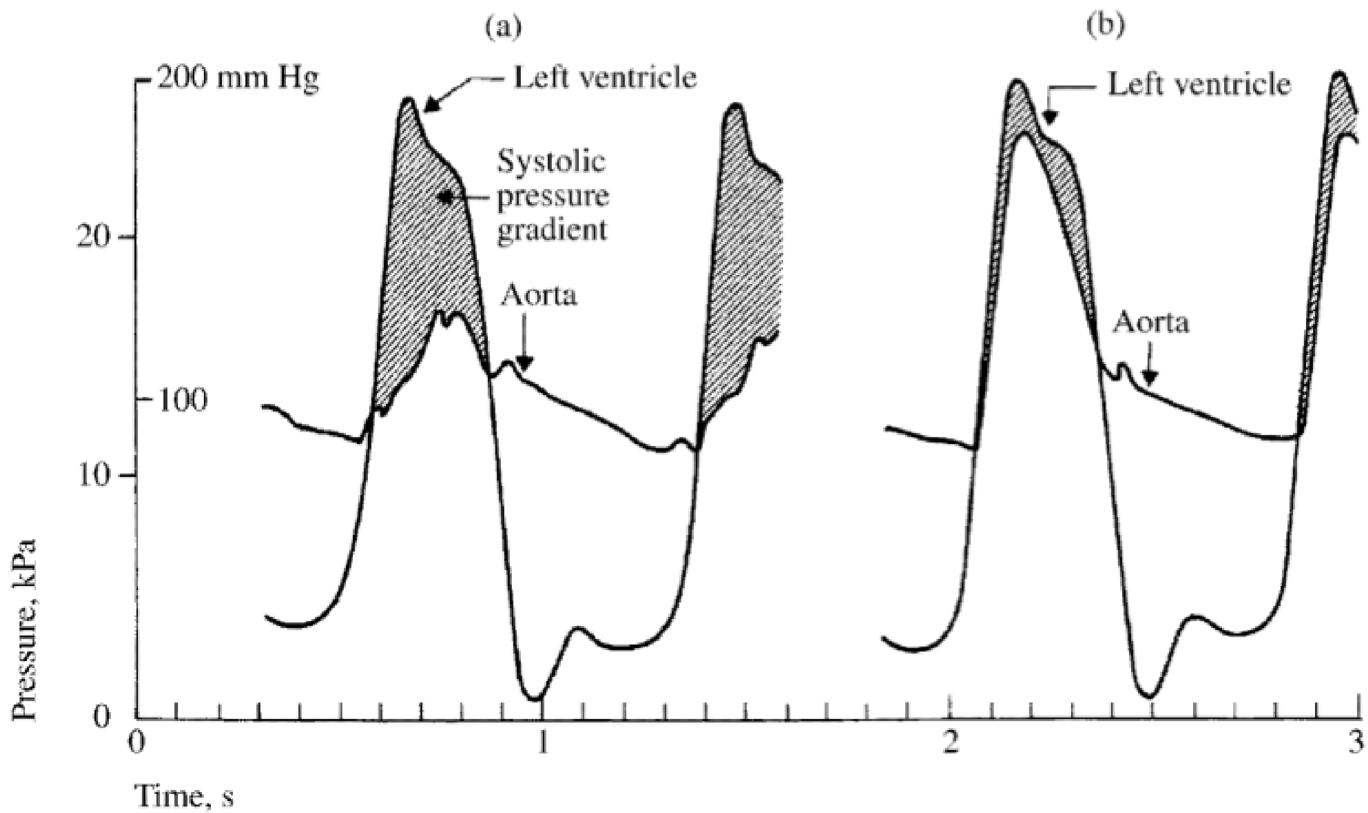


Figure 7.18 (a) Systolic pressure gradient (left ventricular aortic pressure) across a stenotic aortic valve. (b) Marked decrease in systolic pressure gradient with insertion of an aortic ball valve.

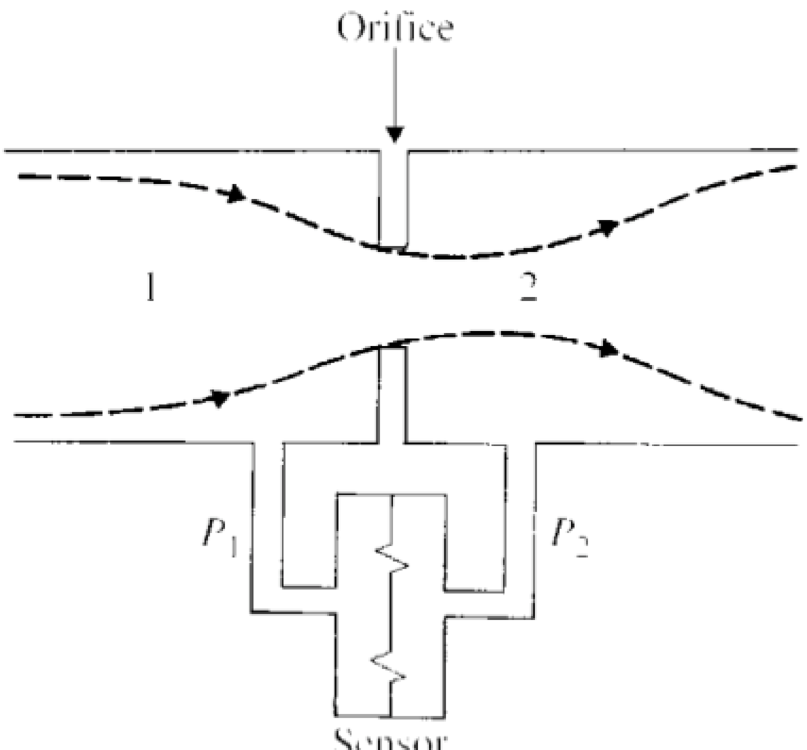
Model for deriving equation for hearth-valve orifice area

- Physicians can assess valvular stenosis by measuring the pressure gradient across the valve of interest and the flow through it.

Bernoulli's equation for frictionless flow (Burton, 1972) is

$$P_t = P + \rho g h + \frac{\rho u^2}{2}$$

P_t = fluid total pressure
P = local fluid static pressure
ρ = fluid density
g = acceleration of gravity (Appendix A.1)
h = height above reference level
u = fluid velocity



$$A = \frac{F}{c_d}\left(\frac{\rho}{2(P_1 - P_2)}\right)^{1/2}$$

Model for deriving equation for heart-valve orifice area : P_1 and P_2 are upstream and downstream static pressures. Velocity u is calculated for minimal flow area A at location 2.