UiO : Department of Physics
University of Oslo



http://www.saga.co.uk/contentlibrary/saga/publishing/verticals/health-and-wellbeing/procedures/blood-pressure-test-1280x960.jpg

FYS 4250

Lecture 3

Case 3



victoriambelisle.blogspot.com

- 61 years old male, previously diagnosed with hypertension and hypercholesterolemia. No other known diseases.

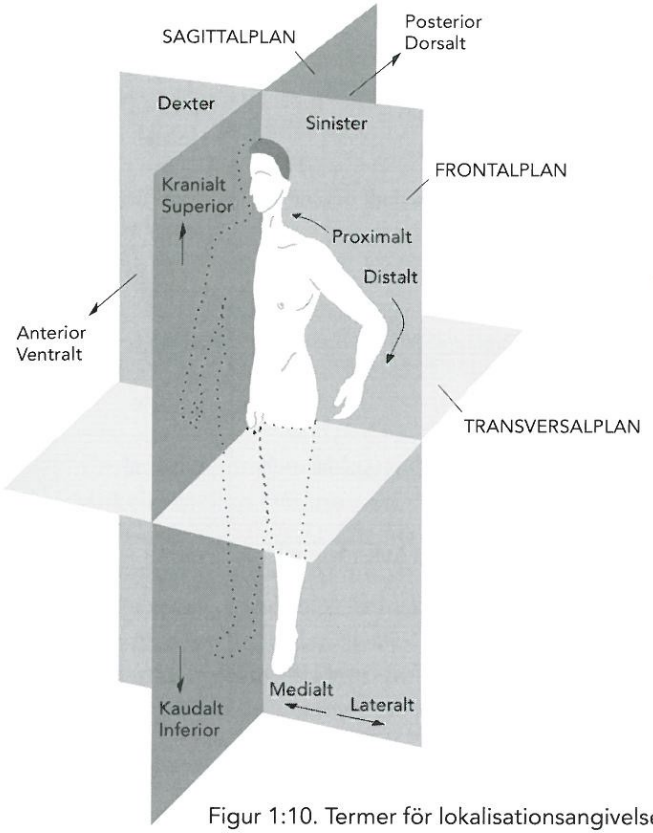
Hypercholesterolemia = high levels of cholesterol in the blood



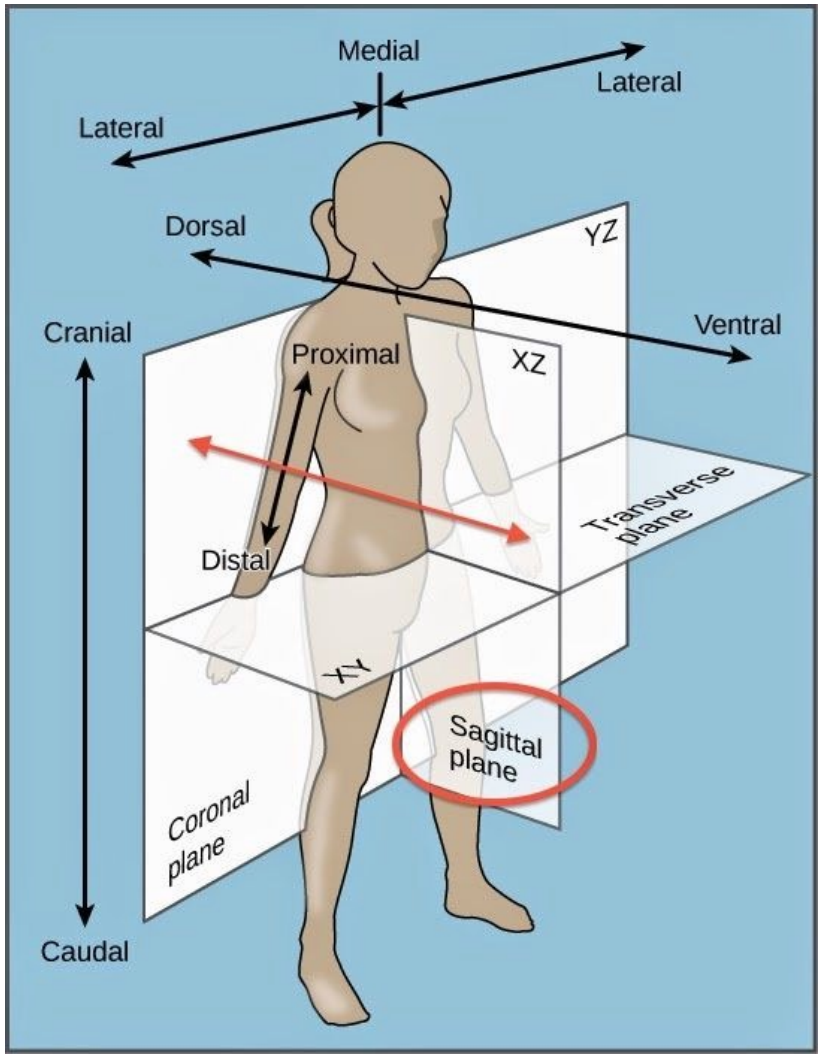
Case 3

- The patient comes and complains about occasional headaches for the last three months, which he believes is a result of increased stress at work. Due to his hypertension and hypercholesterolemia he has lost weight and was prescribed a diuretic.
- He denies chest pain, shortness of breath, dyspnea, or paroxysmal nocturnal dyspnea. He smokes two packs of cigarettes and drinks a couple of glasses of wine with the dinner.
- The patient is obese, BMI = 30 kg/m2. Blood pressure is 190/100 mmHg (right arm) and 192/100 mmHg (left arm), this is not changing with position, heart rate = 84 bpm, right carotid bruit. There is an S4 gallop, no murmurs are auscultated, lung and abdomen examinations are normal, extremities show diminished dorsalis pedis pulses.

- What is the most likely diagnosis?



Figur 1:10. Termer för lokalisationsangivelser.



https:// https://no.pinterest.com/pin/537546905501628162/ -sagittal-plane-anatomy-and-physiology.jpg



Case 3

- We need a reliable blood pressure measurement

- How do we measure the blood pressure?

- First of all, a short repetition of the circulatory system

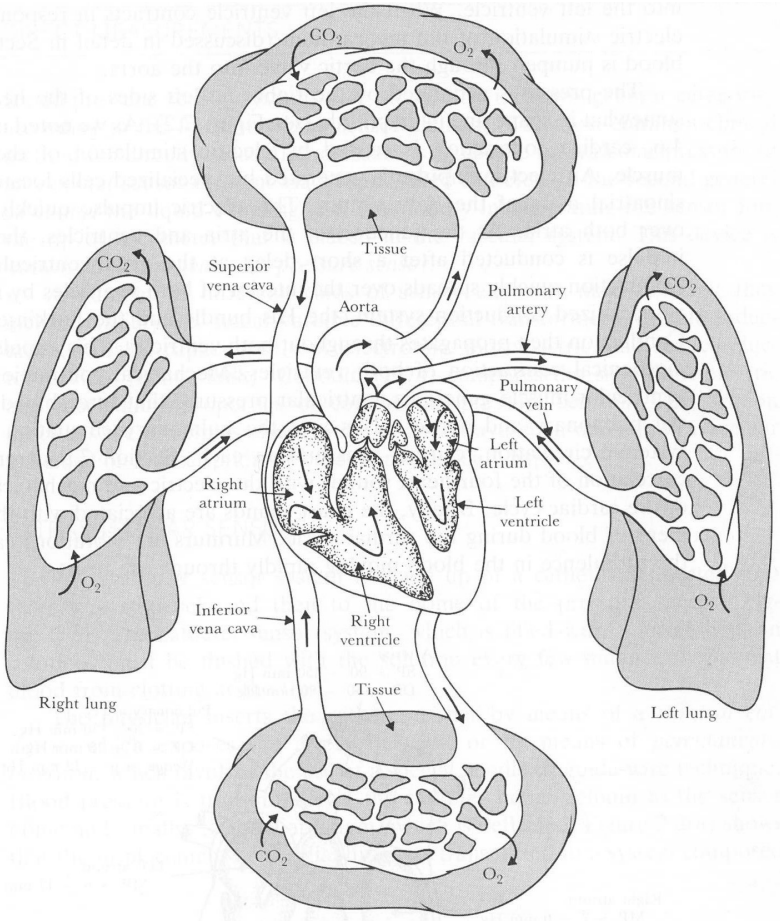


Figure 7.1 The left ventricle ejects blood into the systemic circulatory system. The right ventricle ejects blood into the pulmonary circulatory system.

- Typical pressures, 1kPa = 7.5 mmHg

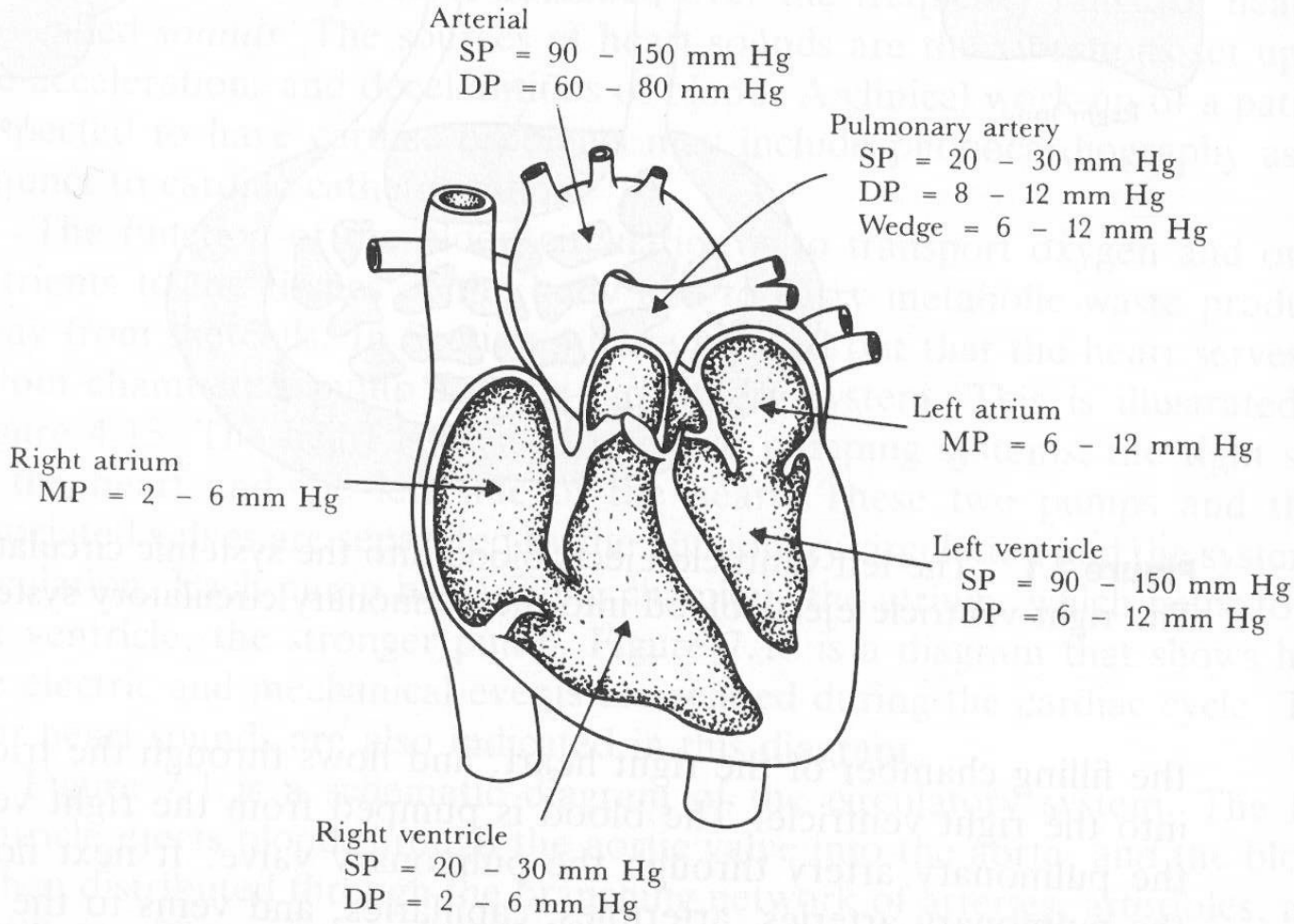


Figure 7.2 Typical values of circulatory pressures SP is the systolic pressure, DP the diastolic pressure, and MP the mean pressure. The wedge pressure is defined in Section 7.13.

What affects the blood pressure?

- The minutevolume of the heart (how much is the heart pumps every minute = stroke volume of the left ventricle * heart rate)
- Ductility of the arteries (one of the reasons for increasing BP with age)
- Perifer resistance (= mainly the diameter of the arterioles (branches of arteries))
- Blood volume
- State of mind (nervous control with the arterioleradius)
- Physical activity
- Digestion



https://www.schiffvitamins.com/blogs/health-wellness/how-to-take-blood-pressure-at-home

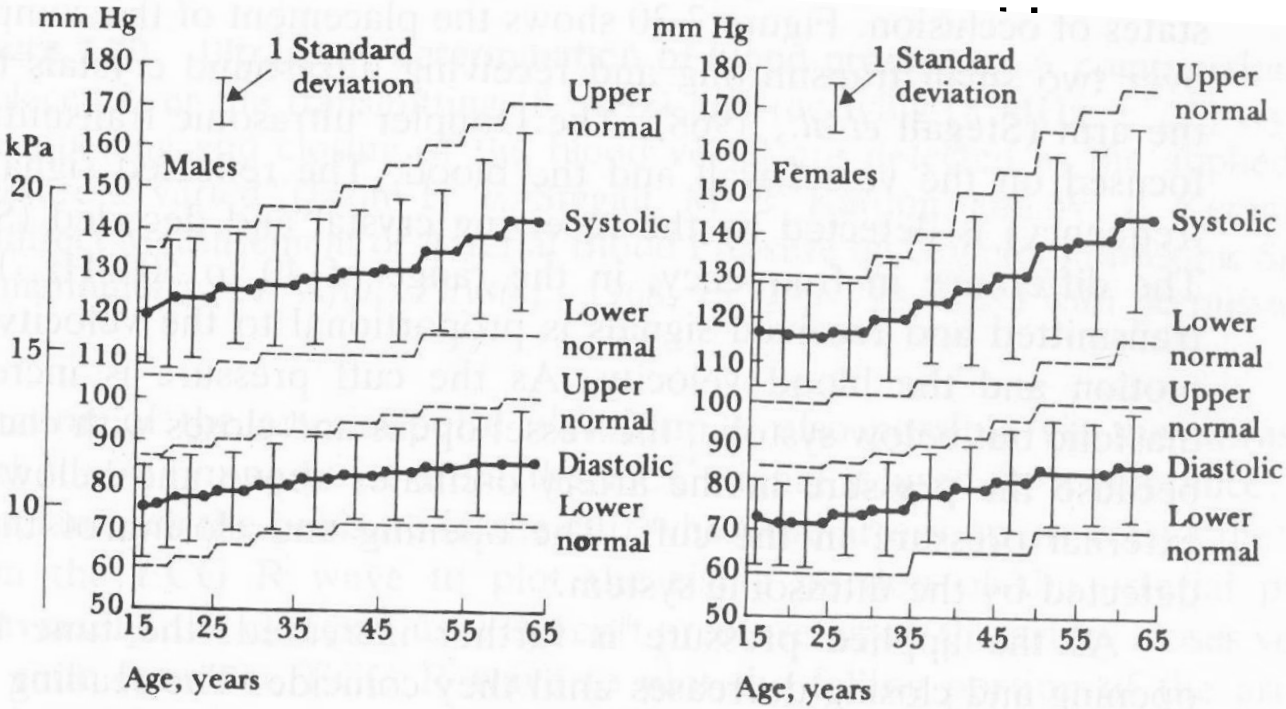


Figure 7.29 Normal values for blood pressure in human males and females, according to age, showing mean systolic and diastolic pressures and plus-and-minus-one standard-deviation range. The limit of normality is given as ±40% of the observations on either side of the mean. [From L. A. Geddes, *The Direct and Indirect Measurement of Blood Pressure*. Copyright © 1970 by Year Book Medical Publishers, Inc., Chicago. Used by permission. (Plotted from data in A. M. Master *et al.*, *Normal Blood Pressure and Hypertension*. Philadelphia: Lea & Febiger, 1952; with permission.)]

What is the problem with hypertension?

Quite normal, affects 20% of all men between 45-50 year

- Increased workload for the heart, more vulnerable to decreased blood-supply to the coronary arteries (supplying the heart)
- Leads to hypertrophy (increased thickness of the heart muscle)
- Increased risk for ruptures in small bloodvessels, could be fatal in the brain, critical in other tissues like the eye (could lead to blindness)
- Increased atherosclerosis (deposition of fatty material on their inner walls)



http://watifhealth.com/what-is-hypertension-and-why-is-it-important-to-be-aware-of-its-symptoms/



Circulatory shock

Compensatory mechanisms are extremely effective, a blood loss of 1,5 L blood of a total of 5-6 liters (70 kg) is not fatal. A bigger loss will lead to organ failure = circulatory shock

Typically a result of decreased minute volume due to:

- Heart attack
- valve failure
- arrythmias

Or reduced venous flow due to:

- Massive bleeding
- Fire-injuries (combustion)
- Diarrhea (long term)

https://healthhearty.com/circulatory-shock-symptoms



Case 3

- There are typically two ways of classifying blood pressure measurement methods, invasive and non-invasive
  - Invasive = into the body
  - Non-invasive = outside the body

- How to measure this?

- Invasive methods
  - Cathetertip
  - Extra-vascular pressure sensor

- Non-invasive methods
  - Sphygmomanometer
  - Oscillometric
  - Ultrasound
  - Microphone



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Invasive methods

- Extra-vascular pressure sensor

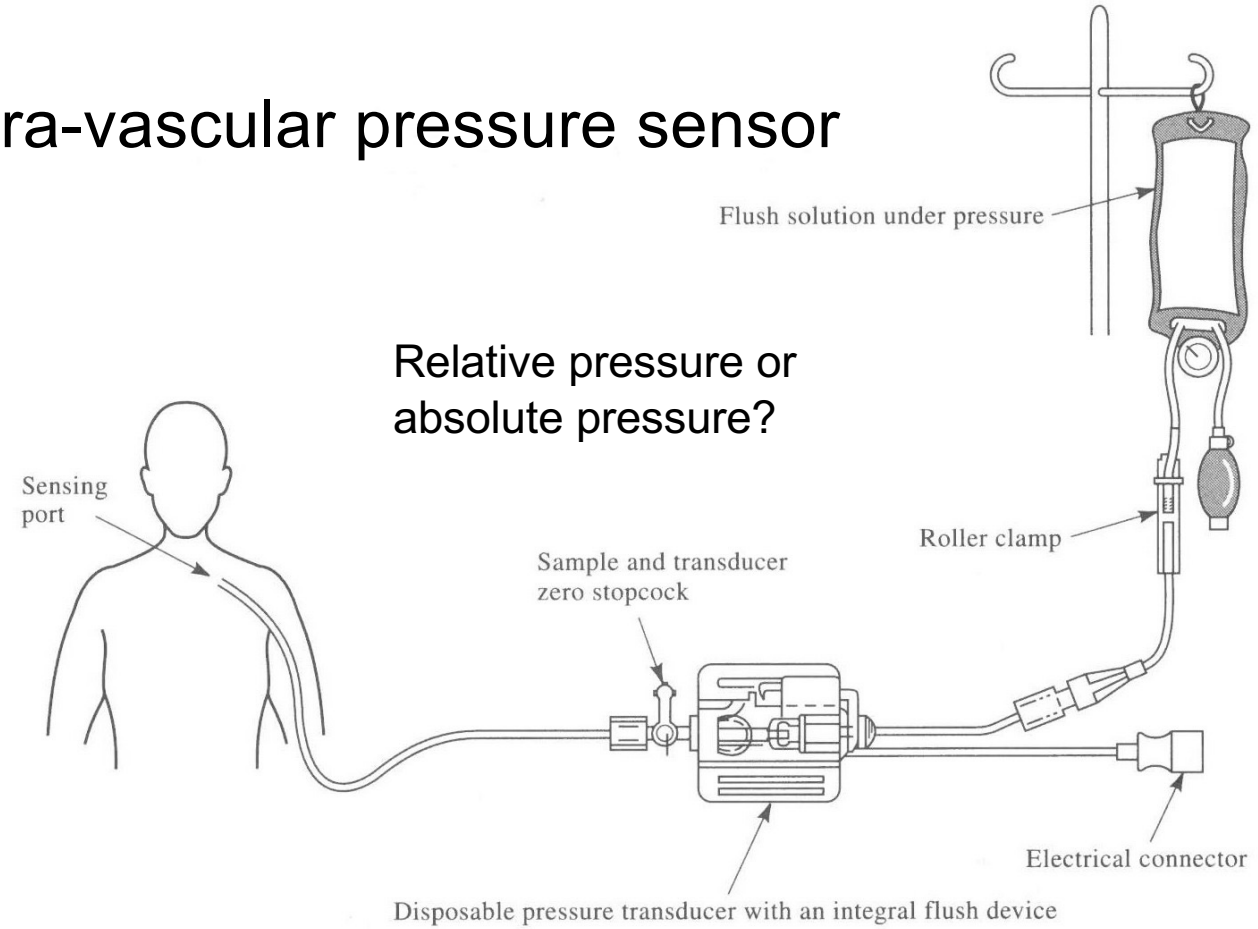
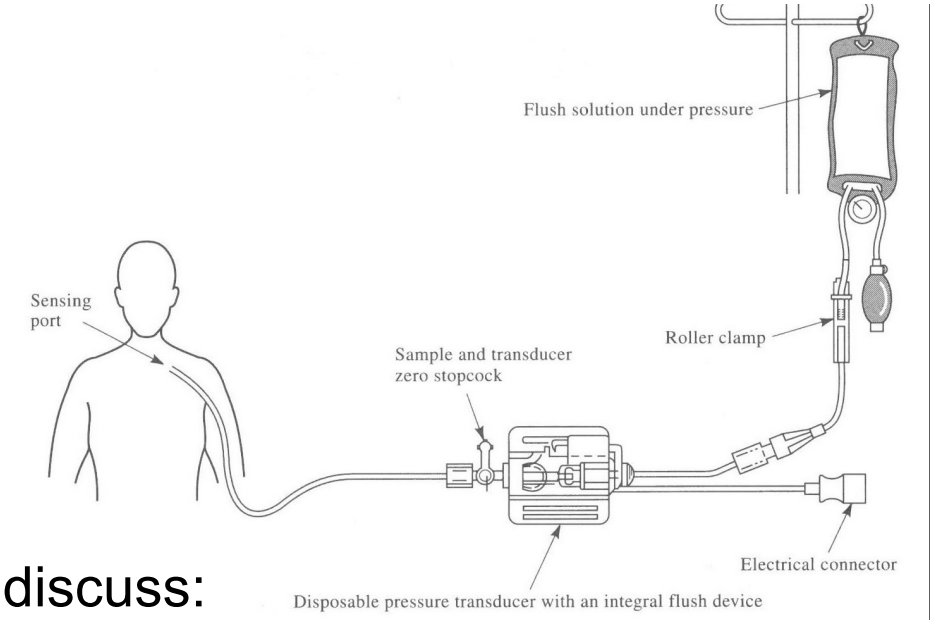


Figure 7.3 Extravascular pressure-sensor system A catheter couples a flush solution (heparinized saline) through a disposable pressure sensor with an integral flush device to the sensing port. The three-way stopcock is used to take blood samples and zero the pressure sensor.

www.Thatsfit.com

Exercise



Form groups of 2 or 3 students, and discuss:

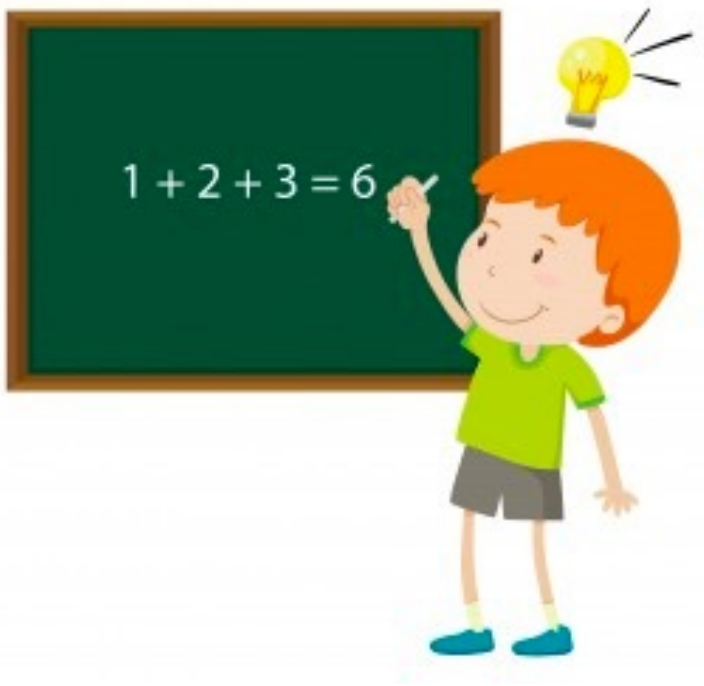
a. What are the typical error sources for extra vascular pressure sensors?

b. Are we measuring absolute or relative pressure?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answers



a. Typical error sources:

- Air bubbles
- Clotting
- Drifting
- Position of sensor
- Catheter properties
- Cannula properties
- Cannula position
- Catheter length
- Sensor housing and properties

b. We measure a relative pressure (to the athmosphere)

Inertia = Inertance
Elasticity = Capacitance
Friction = Resistance

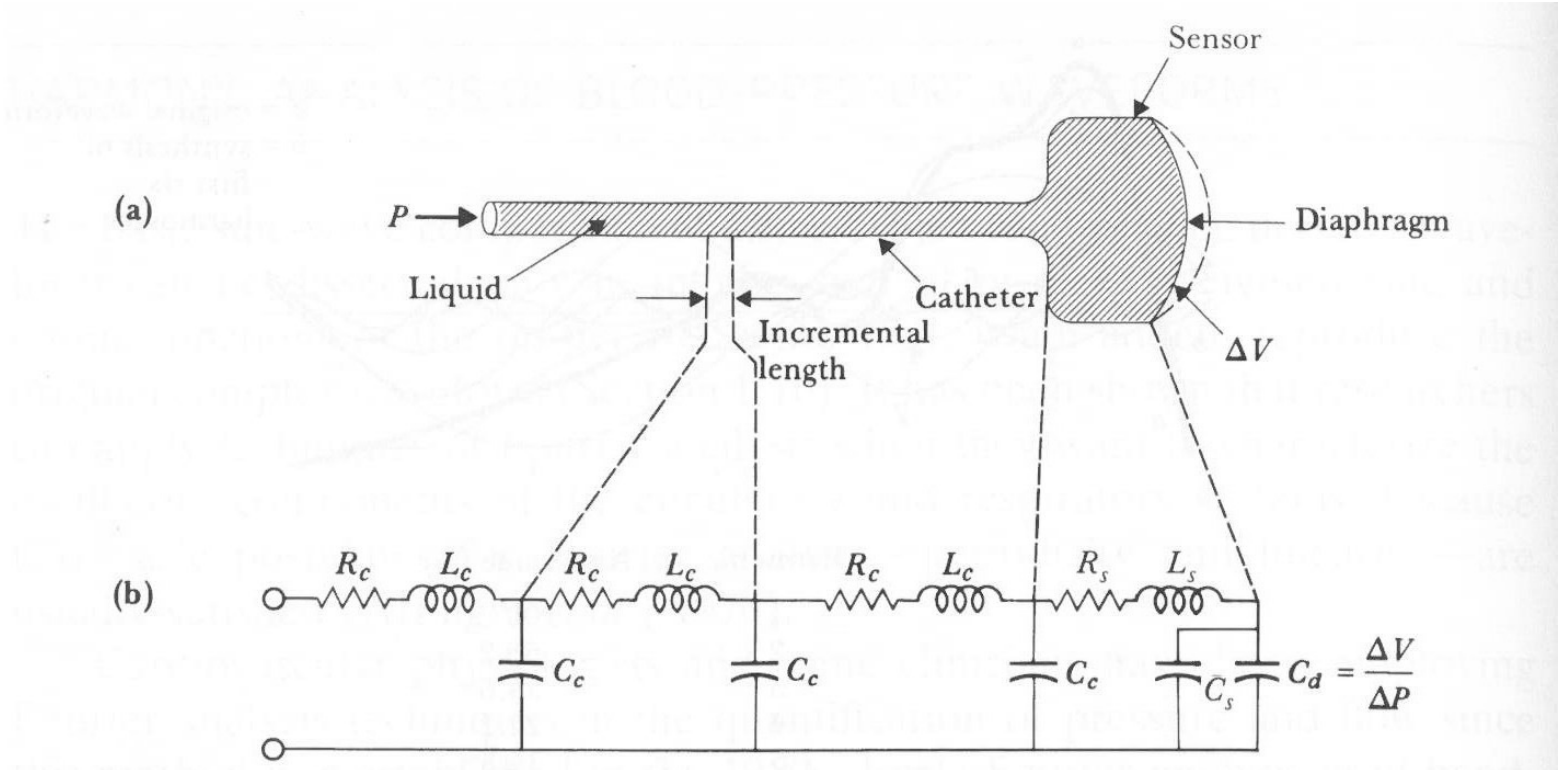


Figure 7.8 (a) Physical model of a catheter-sensor system. (b) Analogous electric system for this catheter-sensor system. Each segment of the catheter has its own resistance R_c, inertance L_c, and compliance C_c. In addition, the sensor has resistance R_s, inertance L_s, and compliance C_s. The compliance of the diaphragm is C_d.

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Inertance

From Wikipedia, the free encyclopedia

This article is about the fluid flow property. For the related mechanical property,

Inertance is a measure of the pressure difference in a fluid required to cause a uni
m^{-4} or Pa m^{-3} s^2 and the usual symbol is **I**.

The inertance of a tube is given by:

$$I = \frac{\rho \cdot \ell}{A}$$

where

ρ is the density (with dimensionality of mass per volume) of the fluid

ℓ is the length of the tube

A is the cross-sectional area of the tube

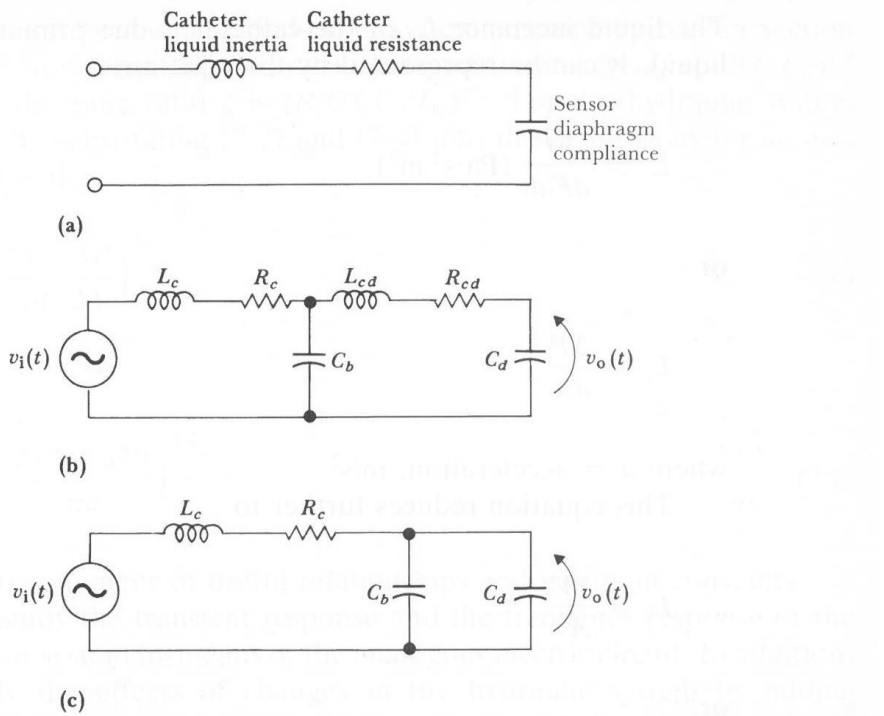
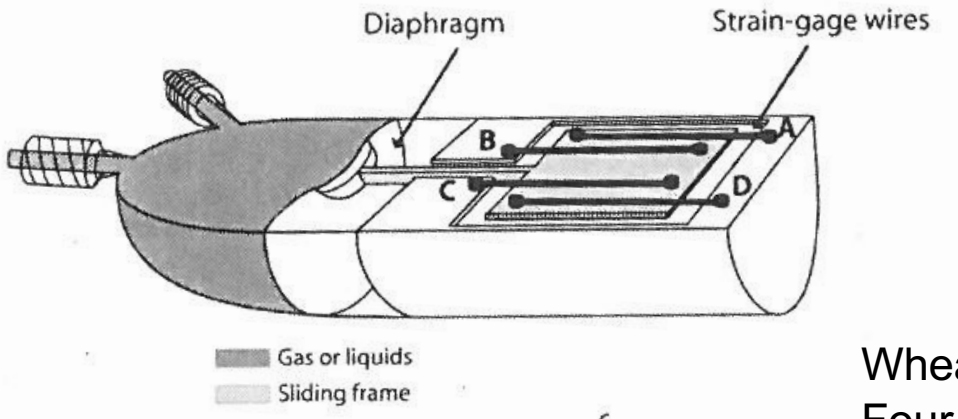
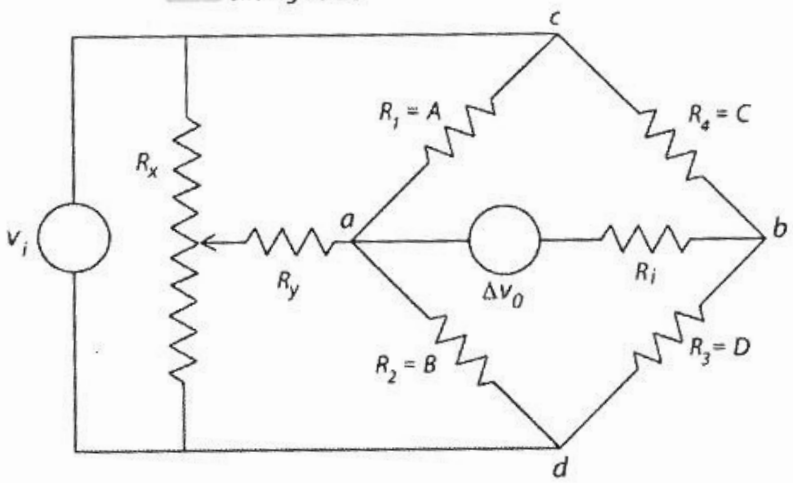


Figure 7.9 (a) Simplified analogous circuit. Compliance of the sensor diaphragm is larger than compliance of catheter or sensor cavity for a bubble-free, noncompliant catheter. The resistance and inertance of the catheter are larger than those of the sensor, because the catheter has longer length and 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) 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.

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- Extra-vascular pressure sensor



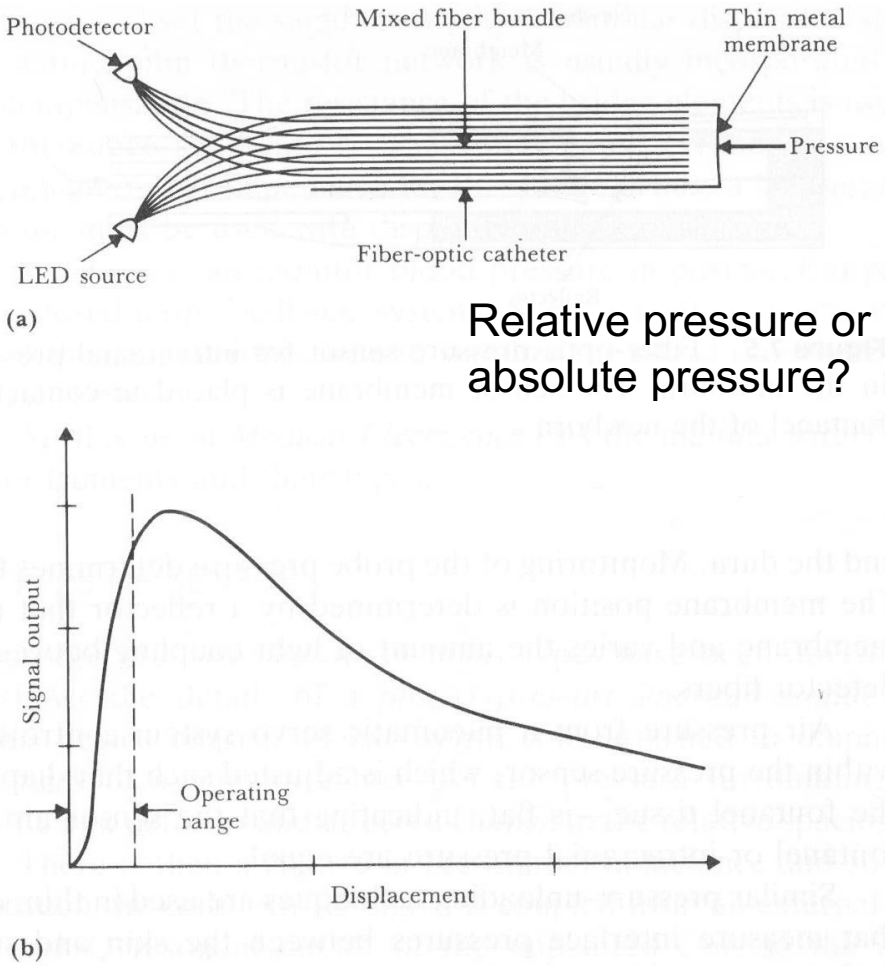


Strain-gages

Wheatstone bridge, balanced
Four times amplification
Temperature compensation

When balanced, R2/R1 = R3/R4

- Intra-vascular pressure sensor



Relative pressure or absolute pressure?

Figure 7.4 (a) Schematic diagram of an intravascular fiber-optic pressure sensor. Pressure causes deflection in a thin metal membrane that modulates the coupling between the source and detector fibers. (b) Characteristic curve for the fiber-optic pressure sensor.

- Intra-vascular pressure sensor

Advantages:
- No limitations in frequency response (no hydraulic system)
- Immediate response
- Blood pressure curves, continuous measurement
- Fiber optic, no risk of electrical shock

Disadvantages:
- Expensive
- Short-lived
- Increased risk of contamination and clotting
- Absolute pressure, not relative
- Catheter whip distortions

Case 3

- Sources of error for invasive methods

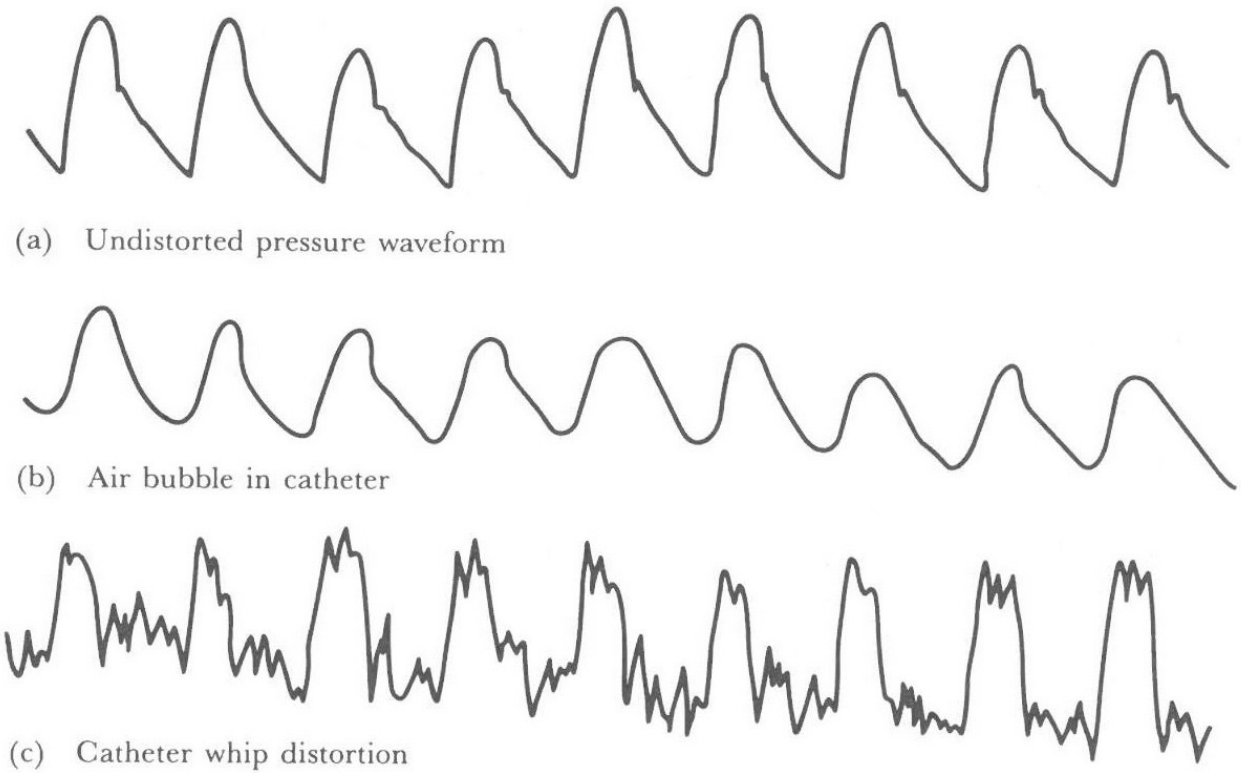


Figure 7.14 Distortion during the recording of arterial pressure The bottom trace is the response when the pressure catheter is bent and whipped by accelerating blood in regions of high pulsatile flow.

- Measuring transient step-response for describing the systems characteristics

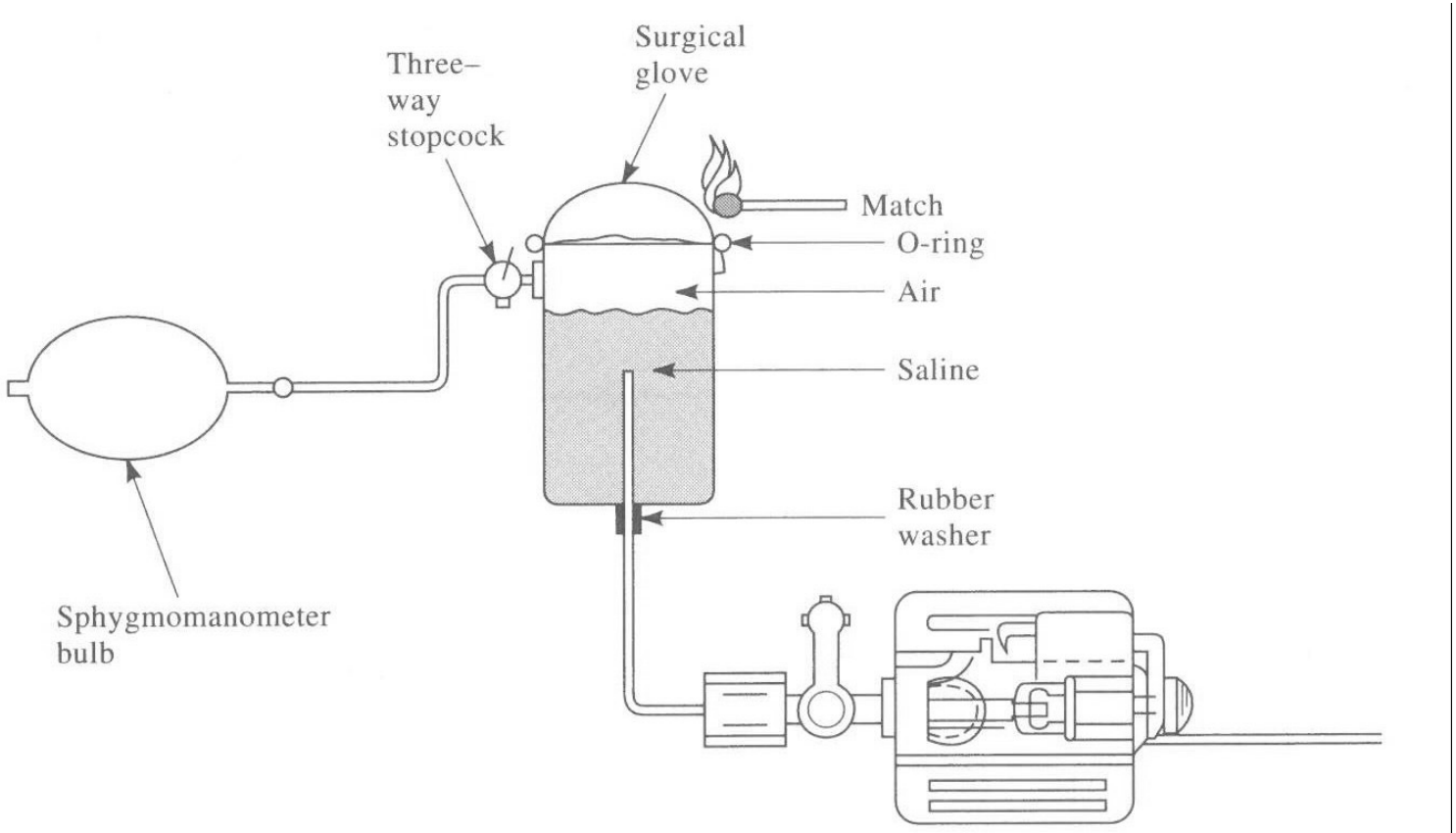


Figure 7.10 Transient-response technique for testing a pressure-sensor–catheter-sensor system.

- Transient step-response could look something like this

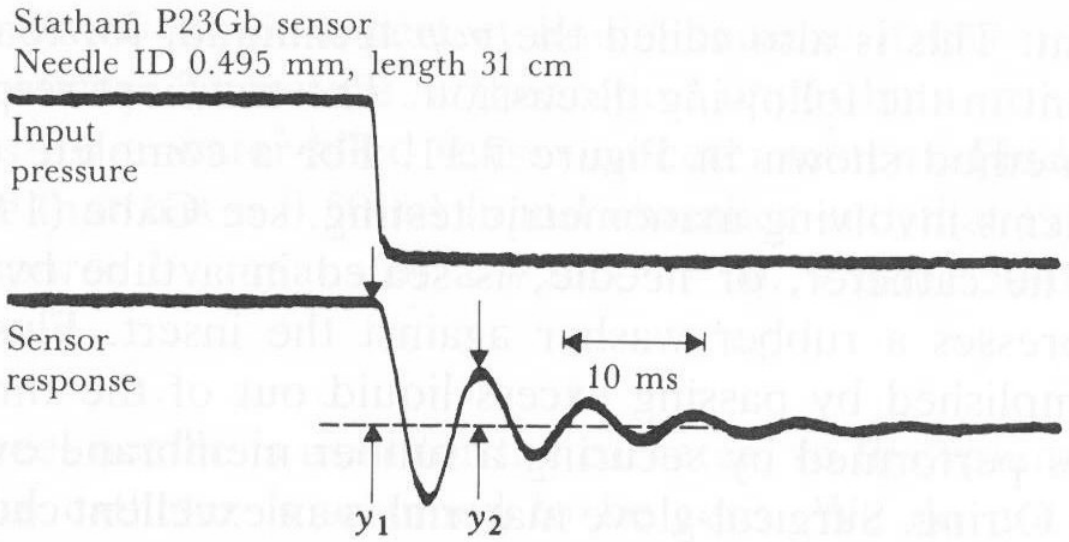


Figure 7.12 **Pressure-sensor transient response** Negative-step input pressure is recorded on the top channel; the bottom channel is sensor response for a Statham P23Gb sensor connected to a 31-cm needle (0.495 mm ID). (From I. T. Gabe, "Pressure Measurement in Experimental Physiology," in D. H. Bergel, ed., *Cardiovascular Fluid Dynamics*, vol. I, New York: Academic Press, 1972.)

- Frequency response testsystem, sine wave

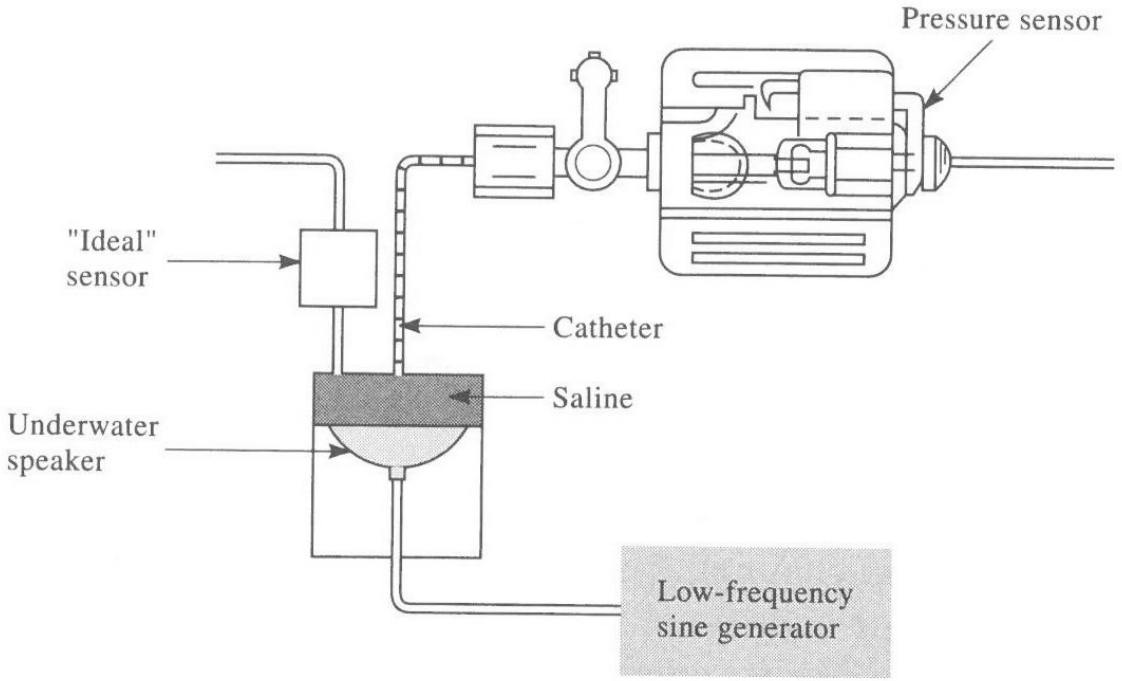


Figure 7.12 A sinusoidal pressure-generator test system A low-frequency sine generator drives an underwater-speaker system that is coupled to the catheter of the pressure sensor under test. An "ideal" pressure sensor, with a frequency response from 0 to 100 Hz, is connected directly to the test chamber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

- Frequency response catheter-sensor system

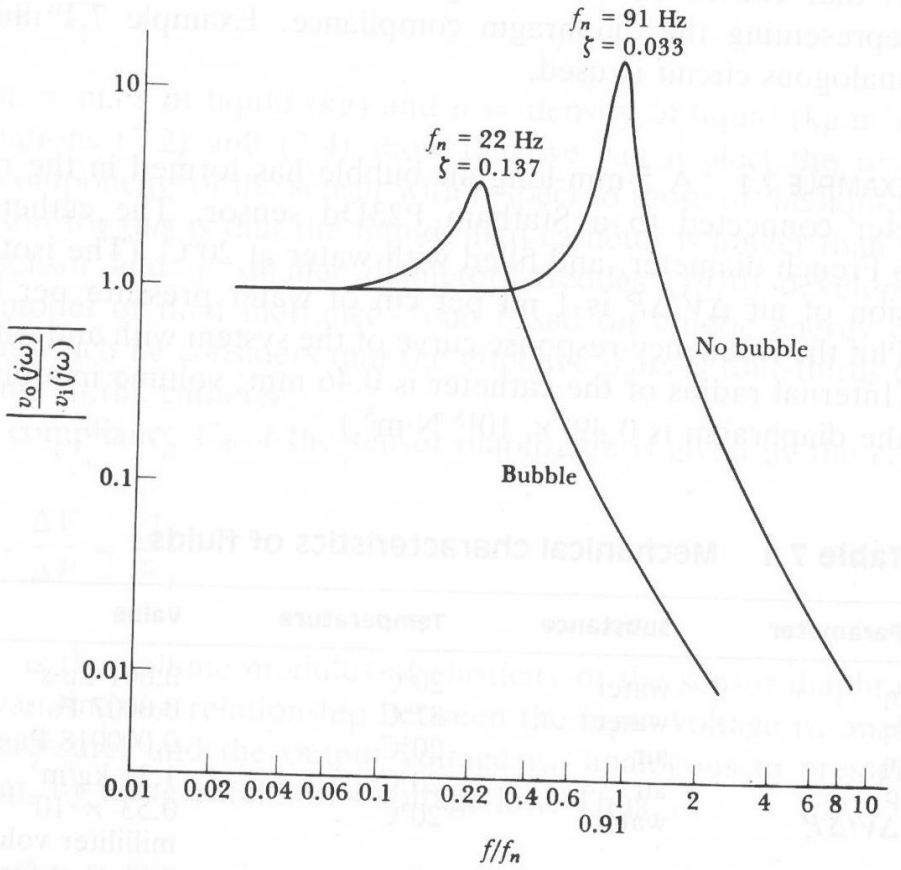


Figure 7.10 Frequency-response curves for catheter-sensor system with and without bubbles. Natural frequency decreases from 91 Hz to 22 Hz and damping ratio increases from 0.033 to 0.137 with the bubble present.

- Frequency response

Aortic valve stenosis

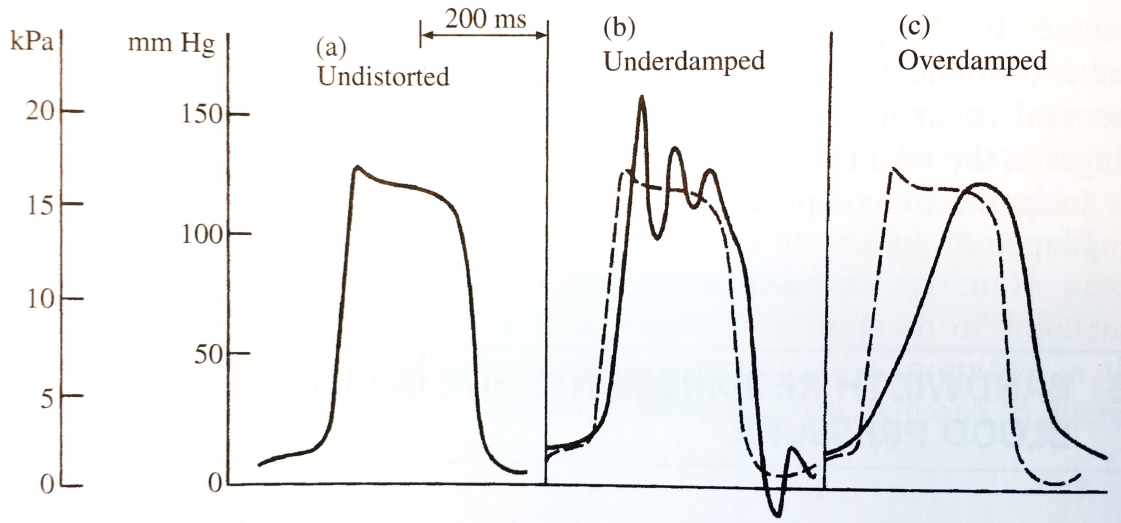
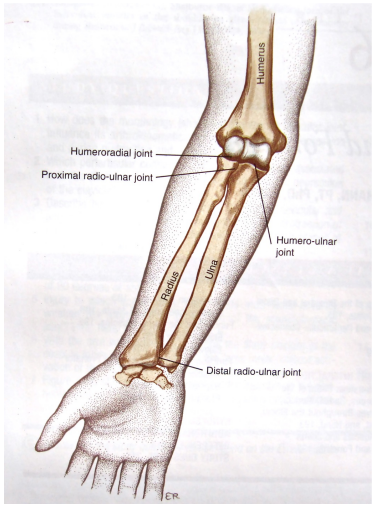


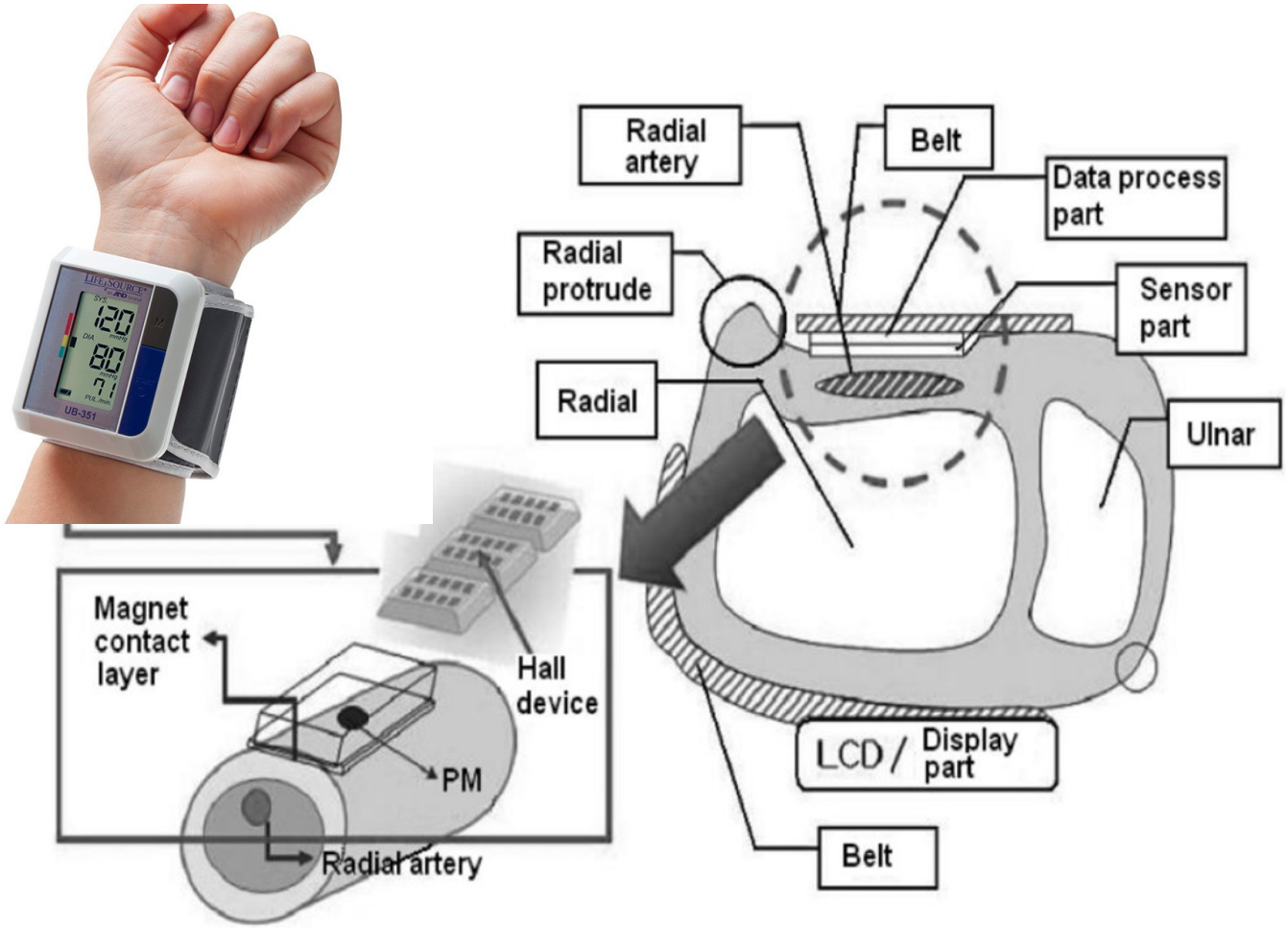
Figure 7.13 Pressure-waveform distortion (a) Recording of an undistorted left-ventricular pressure waveform via a pressure sensor with bandwidth dc to 100 Hz. (b) Underdamped response, where peak value is increased. A time delay is also evident in this recording. (c) Overdamped response that shows a significant time delay and an attenuated amplitude response.

Underdamped system leads to overestimation of the pressure gradients

Non-invasive methods

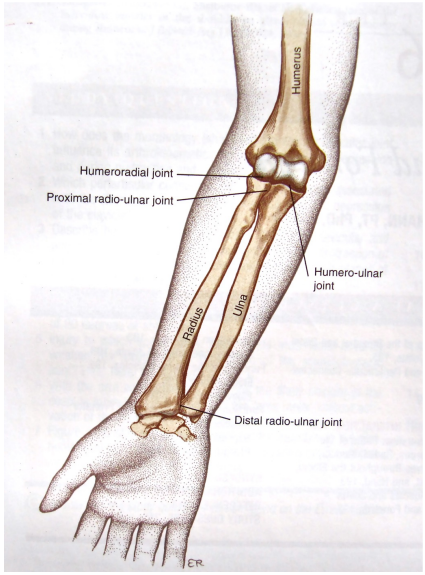
Wrist blood pressure monitors

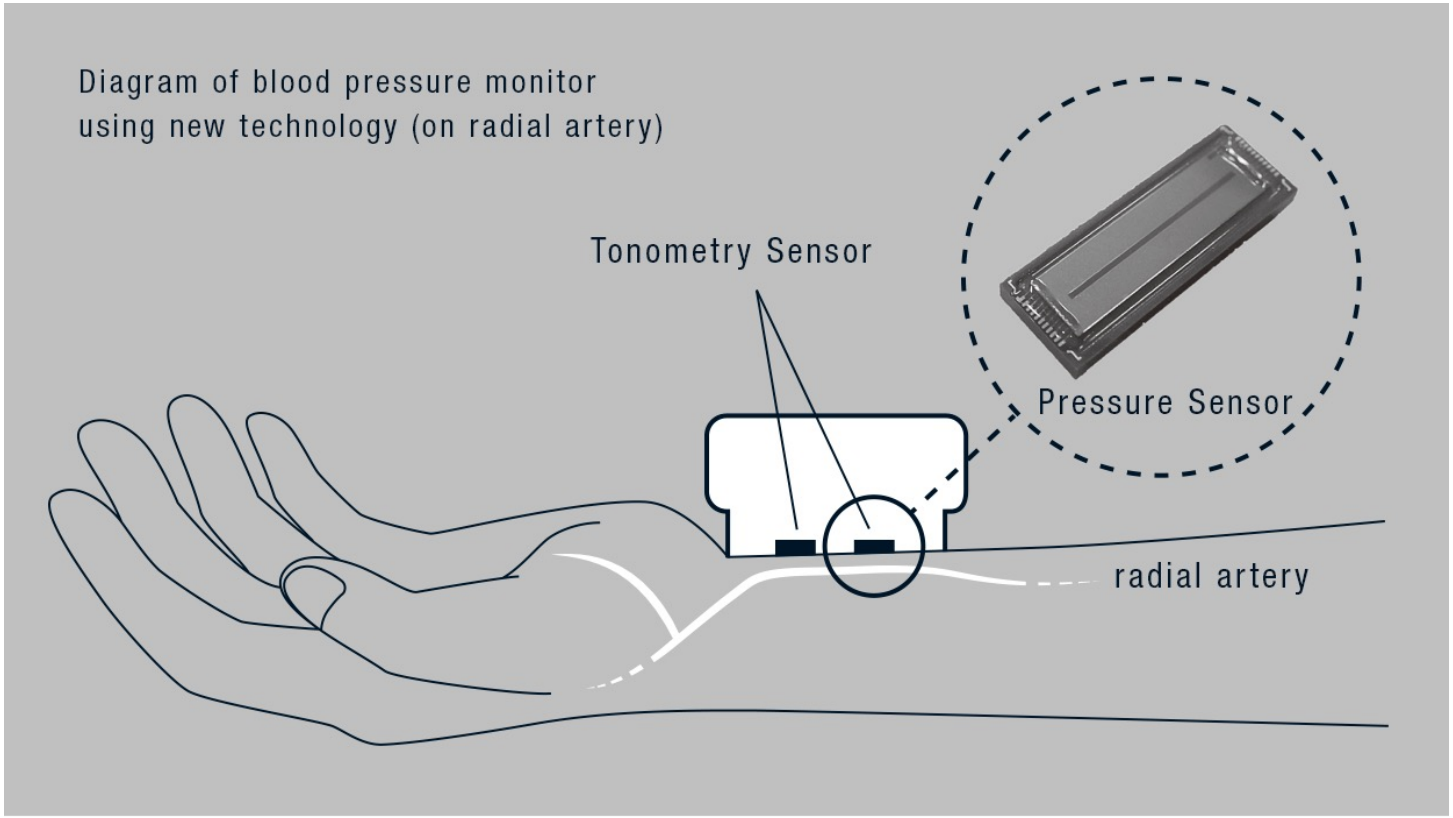




http://payload316.cargocollective.com/1/17/550695/8637651/blood-pressure-monitor-diagram.jpg

Wrist blood pressure monitors





https://www.youtube.com/watch?v=BlJbcJ14iF0#action=share

Exercise

Form groups of 2 or 3 students, and discuss:

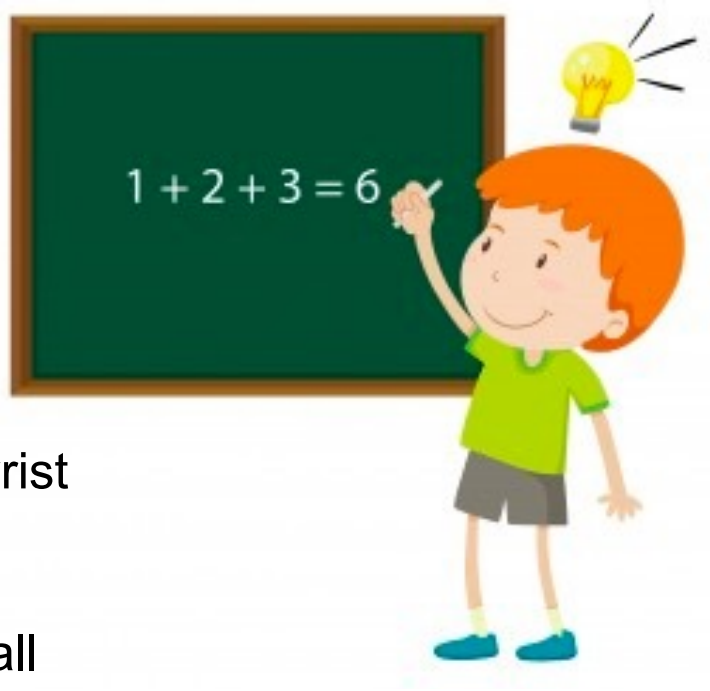
a. What are the typical error sources for wrist blood pressure measurements?

b. What are the advantages?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answers



a. Typical error sources:

- Extremely sensitive to body position
- Sensitive to angle and placement on the wrist
- Less accurate than arm measurements
- Must flatten without occluding
- Dependes on the condition of the artery wall

b. Advantages:

- Easy to use
- Reduced stress for the patient
- Possibility of beat-to-beat continouos monitoring
- Quite accurate when used properly

- Stethoscope



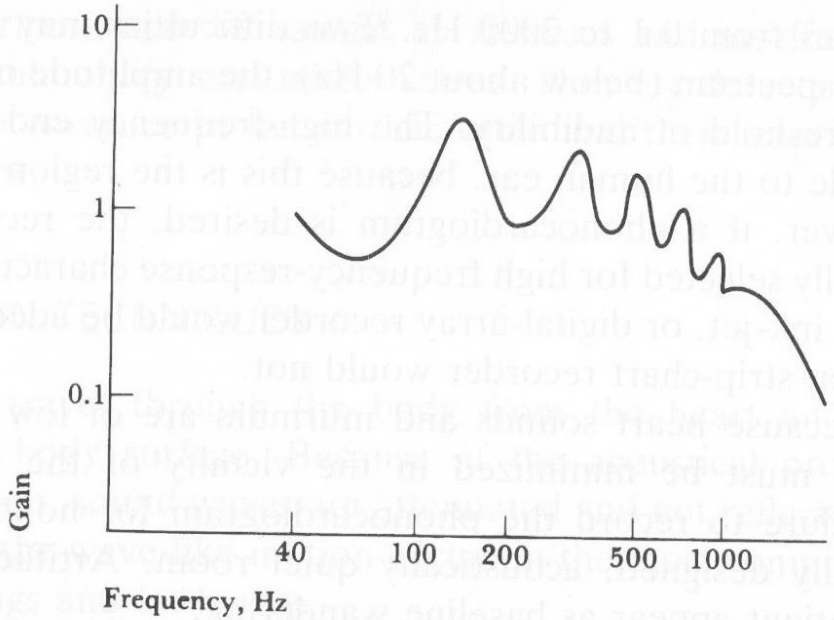


Figure 7.20 The typical frequency-response curve for a stethoscope can be found by applying a known audiofrequency signal to the bell of a stethoscope by means of a headphone-coupler arrangement. The audio output of the stethoscope earpiece was monitored by means of a coupler microphone system. (From P. Y. Ertel, M. Lawrence, R. K. Brown, and A. M. Stern, *Stethoscope Acoustics* I, "The Doctor and his Stethoscope." *Circulation* 34, 1966; by permission of American Heart Association.)

- Why isn't digital stethoscopes a success?

- Heart sounds

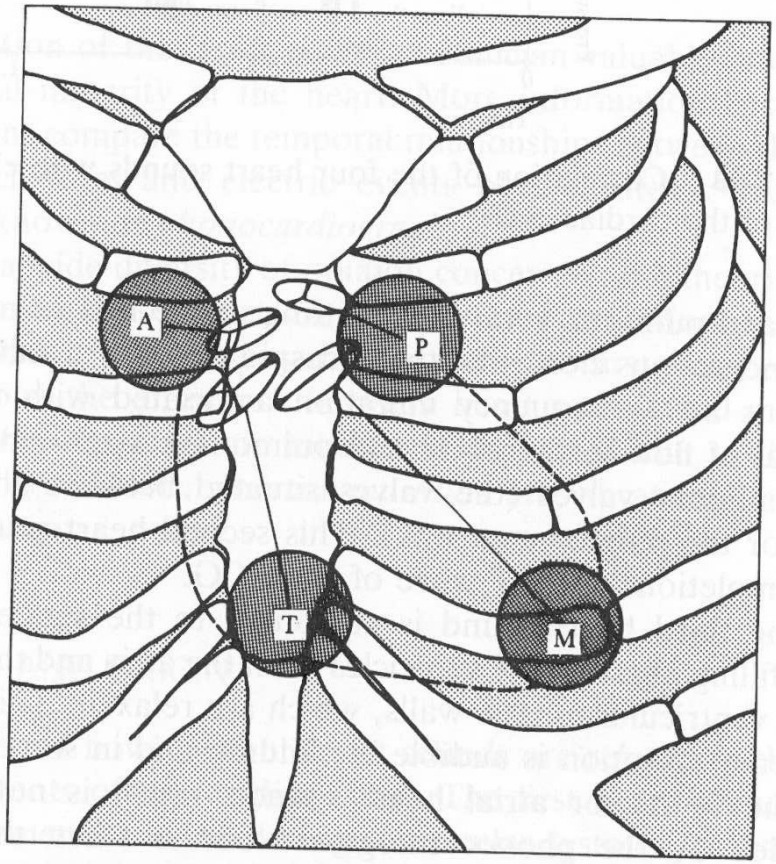


Figure 7.19 **Auscultatory areas on the chest** A, aortic; P, pulmonary; T, tricuspid; and M, mitral areas. (From A. C. Burton, *Physiology and Biophysics of the Circulation*, 2nd ed. Copyright © 1972 by Year Book Medical Publishers, Inc., Chicago. Used by permission.)

- Heart sounds

1.Movement of blood during ventricular systole. Oscillations of blood between the descending root of aorta and ventricle and blood turbulence at the aortic and pulmonary valves
2.Low frequency vibration associated with the deceleration and reversal of flow in the aorta and pulmonary artery and closure of semilunar valves
3.Sudden termination of the rapid filling phase of the ventricles from the atria and the associated vibration of the ventricular muscle walls which are relaxed
4.Not audible, atria contraction

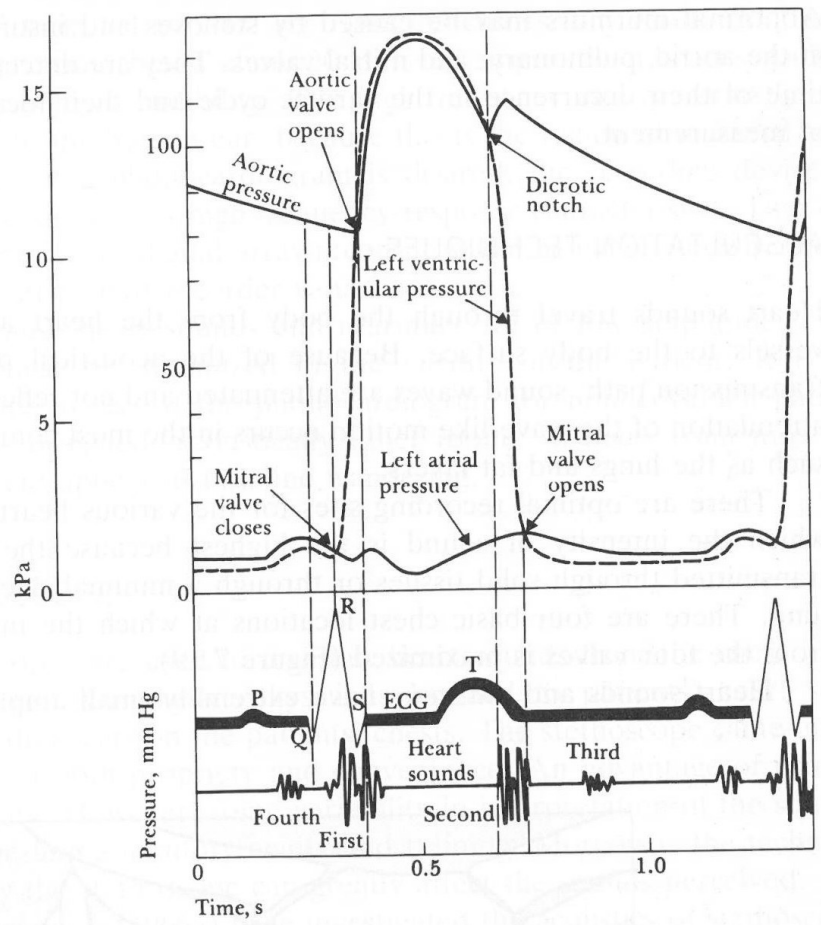


Figure 7.18 Correlation of the four heart sounds with electric and mechani events of the cardiac cycle.

- Sphygmomanometer

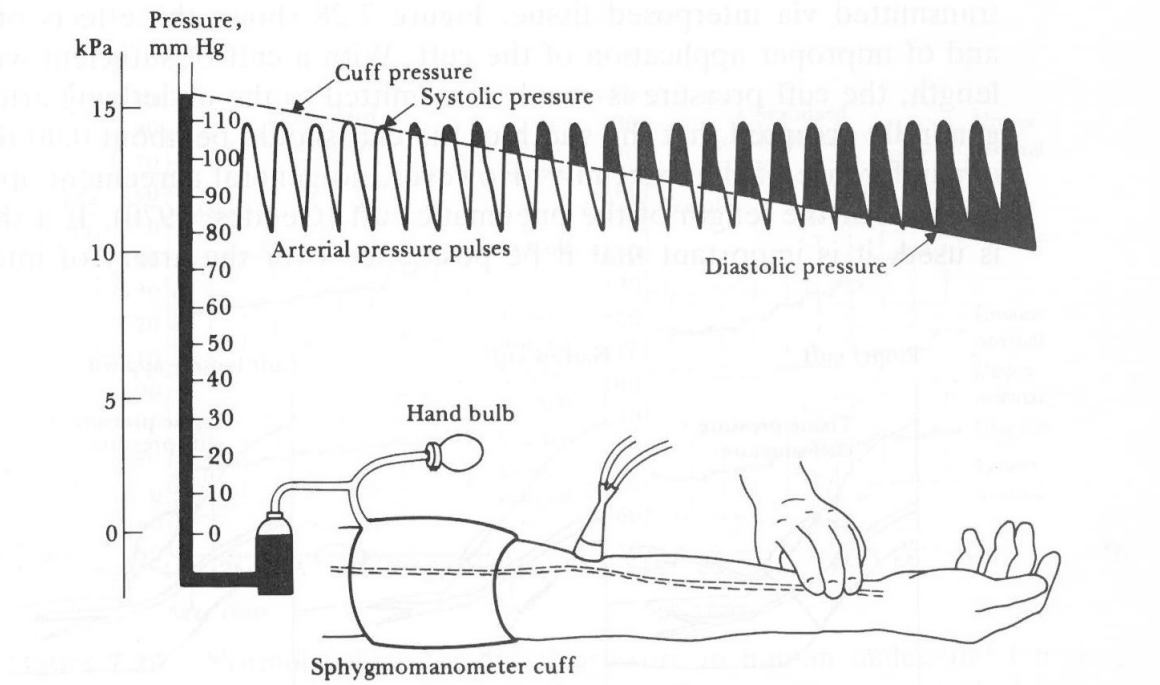


Figure 7.27 Typical indirect blood-pressure measurement system The sphygmomanometer cuff is inflated by a hand bulb to pressures above the systolic level. Pressure is then slowly released, and blood flow under the cuff is monitored by a microphone or stethoscope placed over a downstream artery. The first Korotkoff sound detected indicates 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.)

Exercise

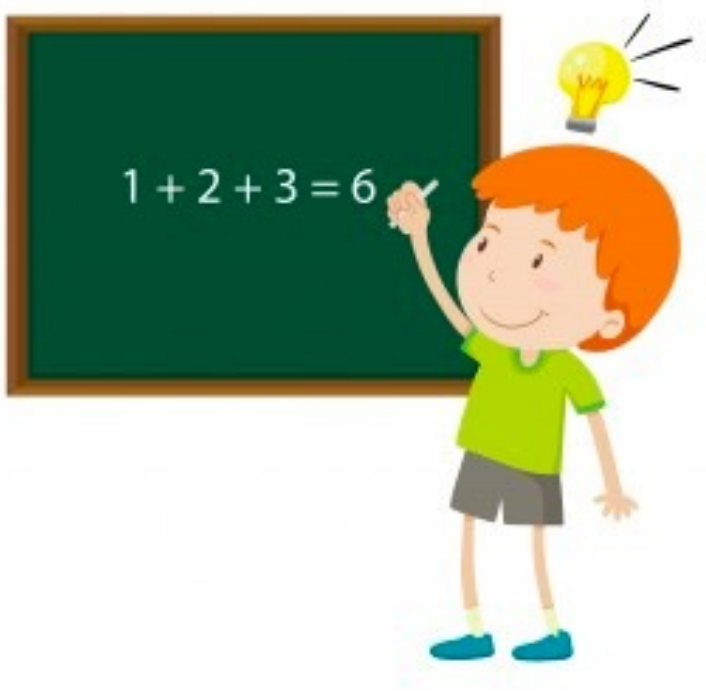
Form groups of 2 or 3 students, and discuss:

a. What are the typical error sources for spyghmomanometers?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answers



a. *Typical error sources:*
   - Position of arm
   - Position of cuff
   - Manometer accuracy
   - Sound apprehension
   - Cuff size
   - Clothes
   - Tube properties
   - Stethoscope properties
   - Other…..

Case 3

- Oscillometric

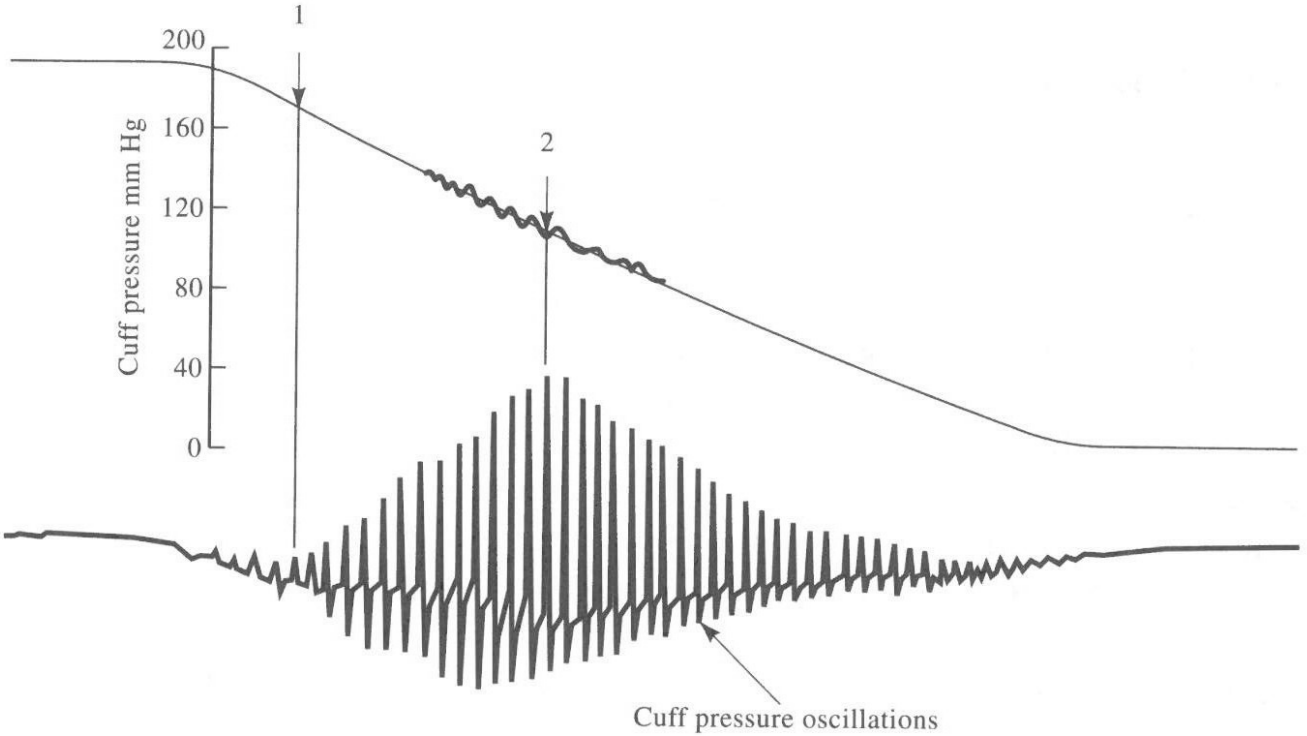


Figure 7.22 The oscillometric method A compression cuff is inflated above systolic pressure and slowly deflated. Systolic pressure is detected (Point 1) where there is a transition from small amplitude oscillations (above systolic pressure) to increasing cuff-pressure amplitude. The cuff-pressure oscillations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

- Oscillometric sources of error?
  - Mechanical interference
  - Pressure sensor properties
  - Tube properties
  - Cuff
  - Clothes
  - Sensor posistion
  - Diastolic pressure is calculated, not measured
  - ++

- Ultrasound

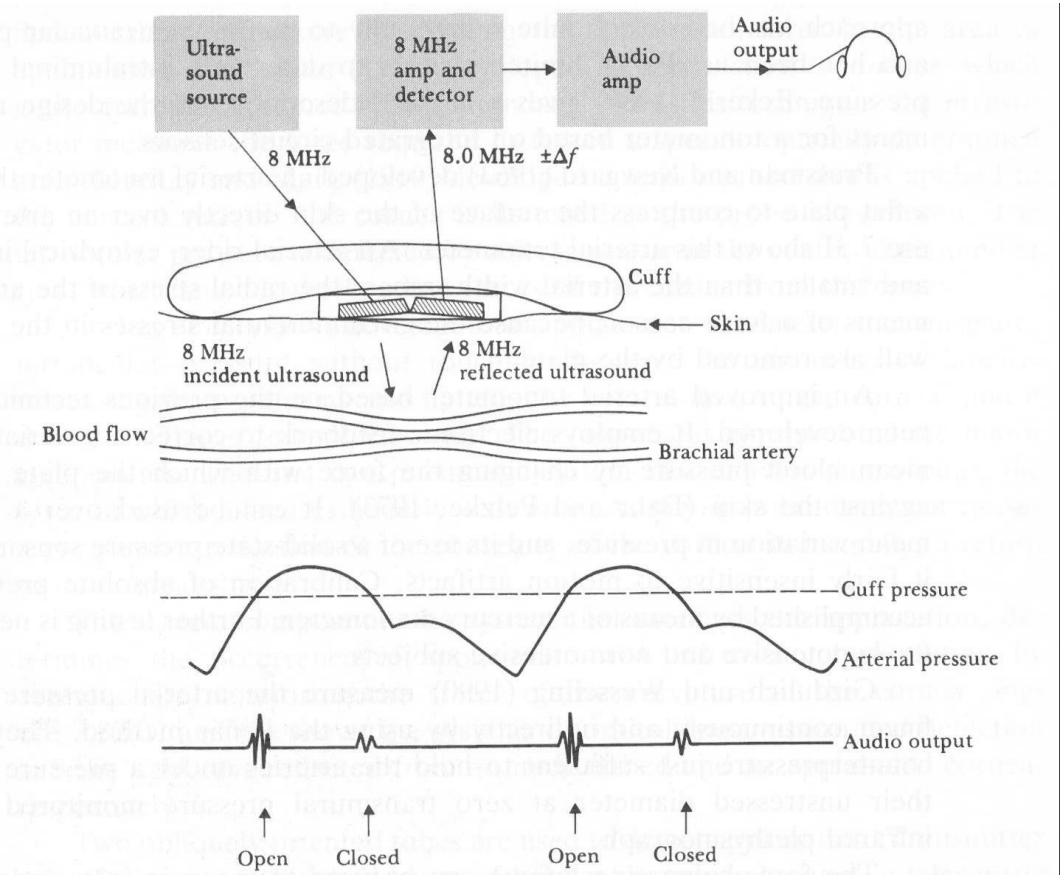
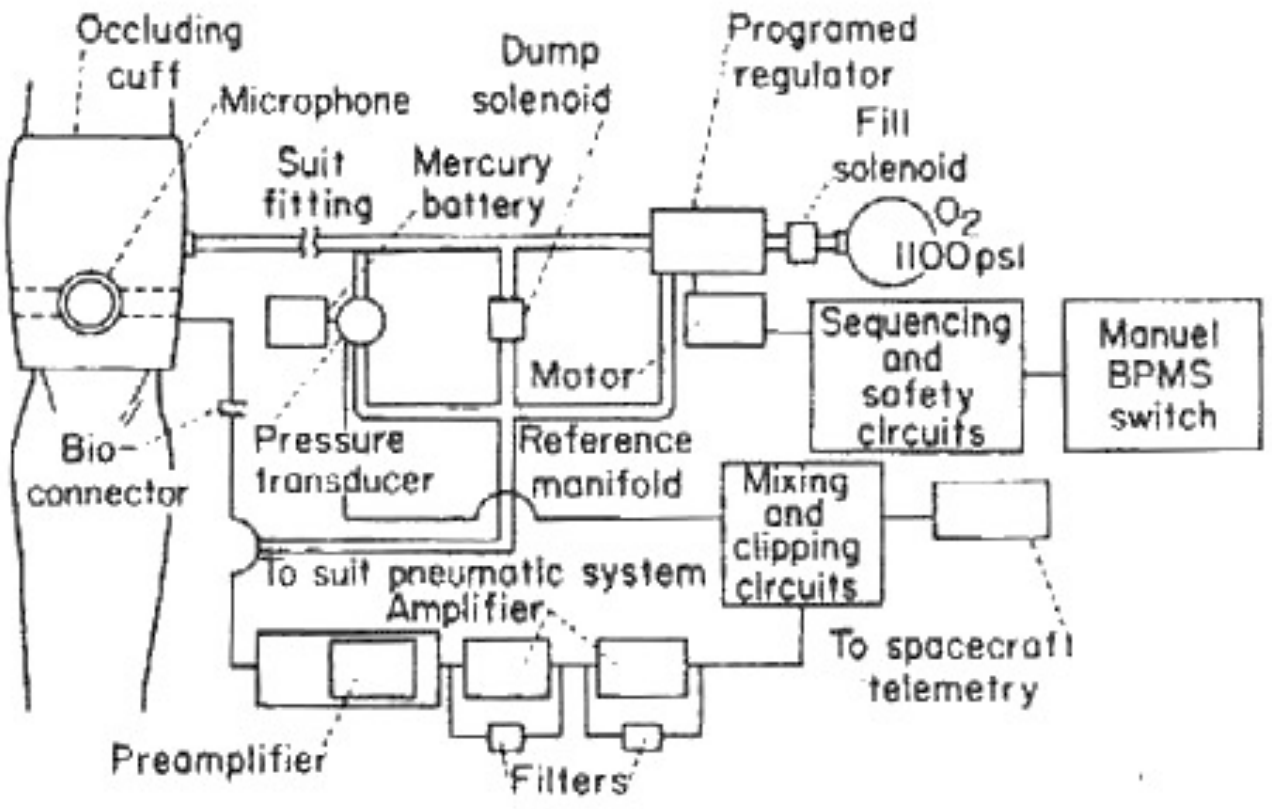


Figure 7.30 Ultrasonic determination of blood pressure A compression cuff is placed over the transmitting (8 MHz) and receiving (8 MHz ± Δf) crystals. The opening and closing of the blood vessel are detected as the applied cuff pressure is varied. (From H. F. Stegall, M. B. Kardon, and W. T. Kemmerer, "Indirect Measurement of Arterial Blood Pressure by Doppler Ultrasonic Sphygmomanometry," *J. Appl. Physiol.*, 1968, 25, 793–798. Used with permission.)

- Ultrasound sources of error
  - Vulnerable to movements of the subject's body
  - All the regular cuff things…..

- Microphone



Source: www.nasa.gov

- Microphone

Advantages:
- Simple
- Automated

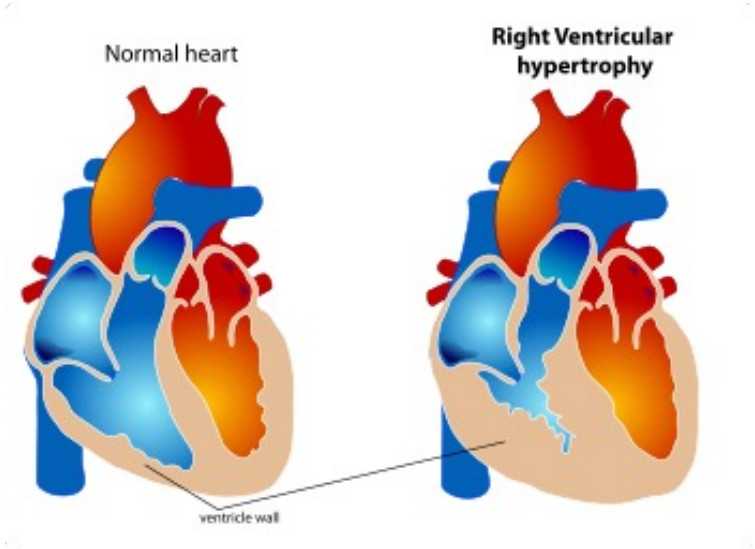
Disadvantages:
- Extremely vulnerable to the positioning of the cuff
- Other sounds could interfere
- Less reliable compared to other methods

Source: www.nasa.gov

Case 3



- His primary doctor diagnose him with severe hypertension with evidence, on physical examination, of hypertensive end-organ damage, probably left ventricular hypertrophy. He gives anti-hypertensiva, but two-drug therapy has no effect on the blood pressure. The patient is then admitted to hospital for a thoroughly examination.

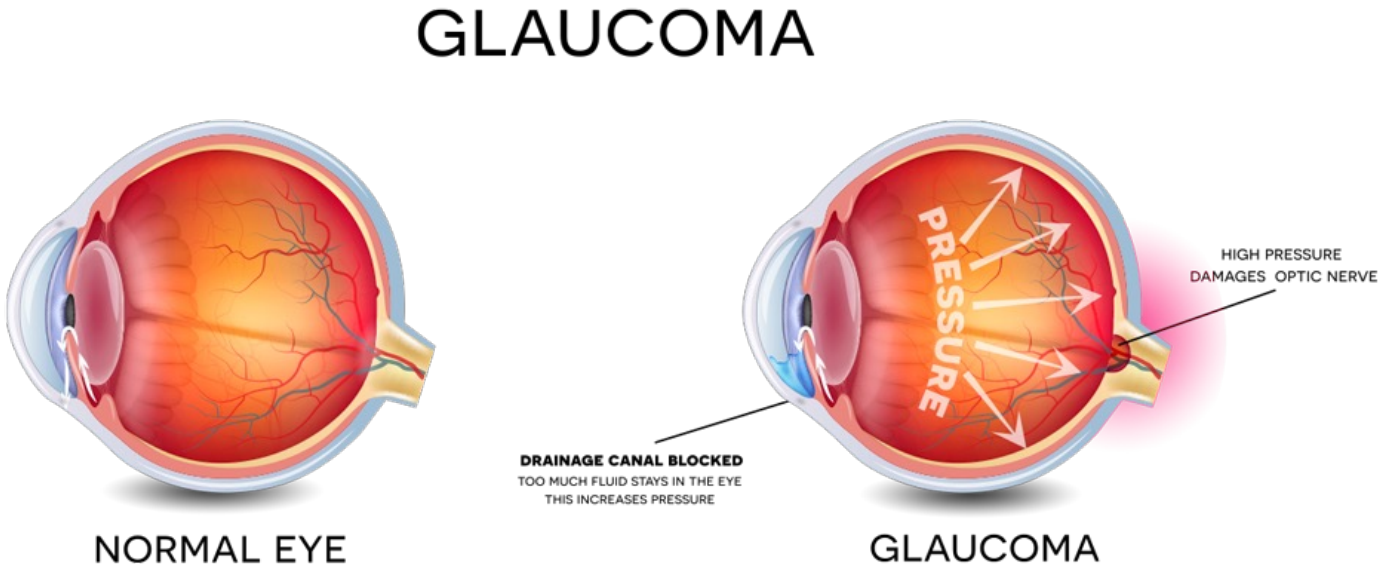


https://upload.wikimedia.org/wikipedia/commons/thumb/3/39/Right_Ventricular_hypertrophy.svg/350px-Right_Ventricular_hypertrophy.svg.png



Case 3

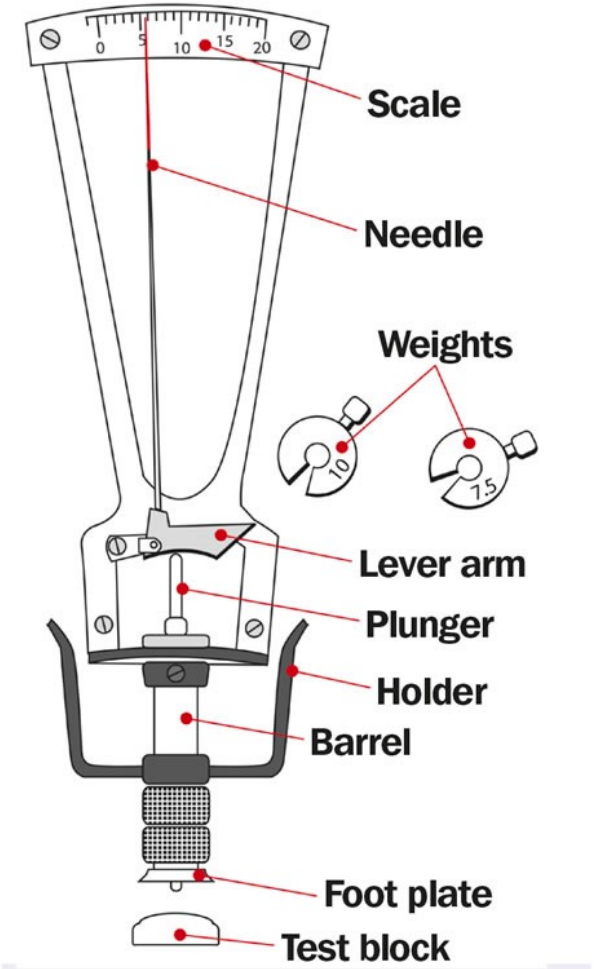
- The physicians believe he has a gradually progressive visual field loss which is an early indicator of glaucoma. This will not be experienced by the patient himself because the brain will compensate for the lost visual information in the same way that it compensates for the blind spot in the eye.



http://brandoneye.com/wp-content/uploads/2015/07/glaucoma.png

Newtons third law and P=F/A

- Tonometry, the classical way (Schiøtz tonometer)
- Measuring the intra-ocular pressure



Scale reading	Ocular pressure, mmHg: 5.5 g weight	Ocular pressure, mmHg: 7.5 g weight	Ocular pressure, mmHg: 10.0 g weight
3.0	24.4	35.8	50.6
4.0	20.6	30.4	43.4
5.0	17.3	25.8	37.2
6.0	14.6	21.9	31.8
7.0	12.2	18.5	27.2
8.0	10.2	15.6	23.1
9.0	8.5	13.1	19.6
10.0	7.1	10.9	16.5

Press the foot plate against chornea, and read the pressure from the scale

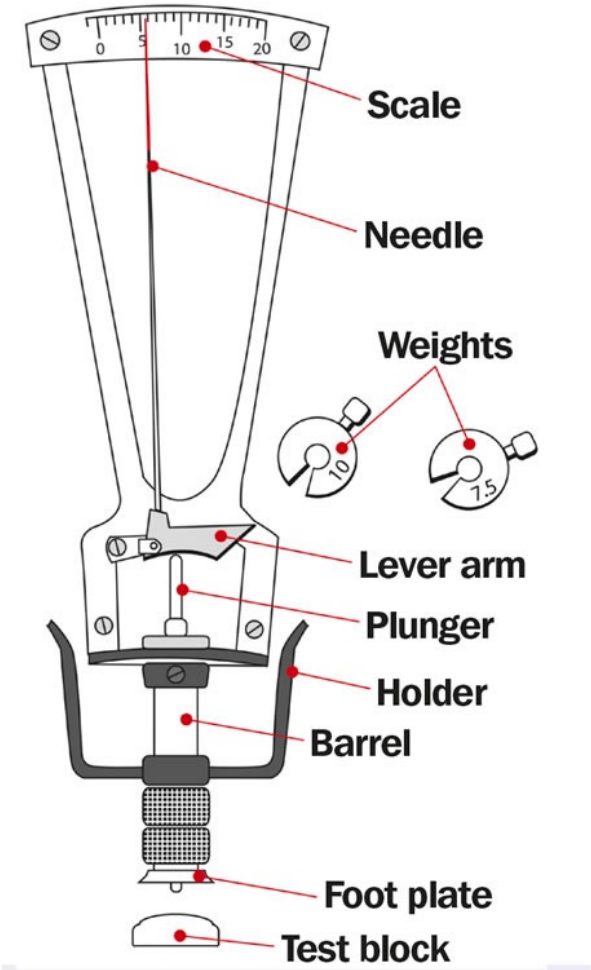
Principle: When a pressureized vessel is partly collapsed by an external object, circumferential stresses in the vessel wall are removed and the internal and external pressures are equal.

https://www.cehjournal.org/article/understanding-and-caring-for-a-schiotz-tonometer/

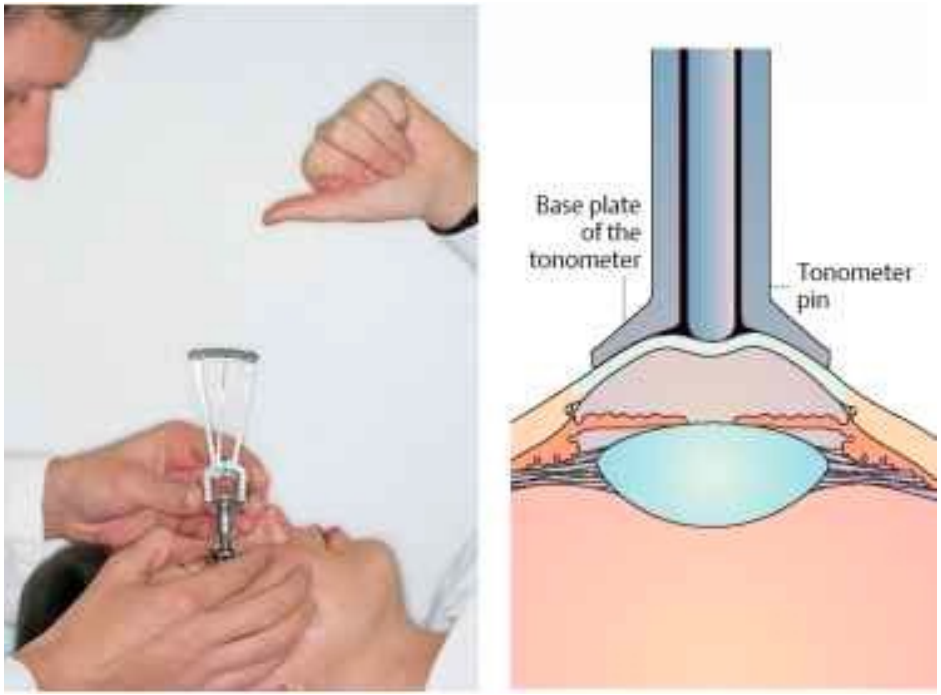


Case 3

- Tonometry, the classical way (Schiøtz tonometer)



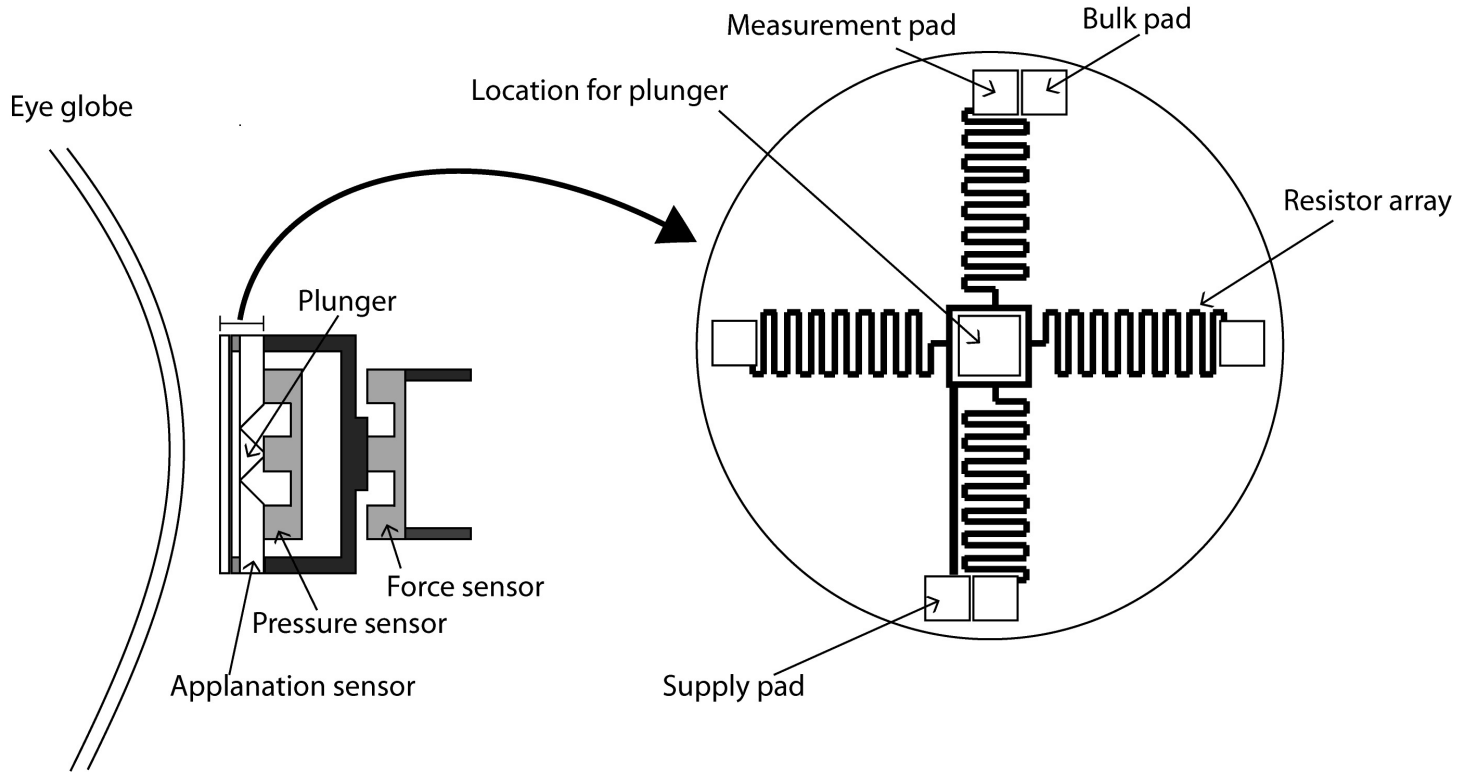
How do we know that we apply the right pressure?



https://www.alpfmedical.info/visual-acuity/pupil.html

Flattening diameter = 3.06 mm

- Contact tonometry, automized



Prerequisitions: Cornea is infinitely thin, perfectly elastic, perfectly flexible

Internal pressure can be calculated by measuring the necessary force F that can flatten a certain area (A) of the sphere p=F/A

Best correction if the flattened area has a diameter of 3.06 mm

- Non-contact tonometry

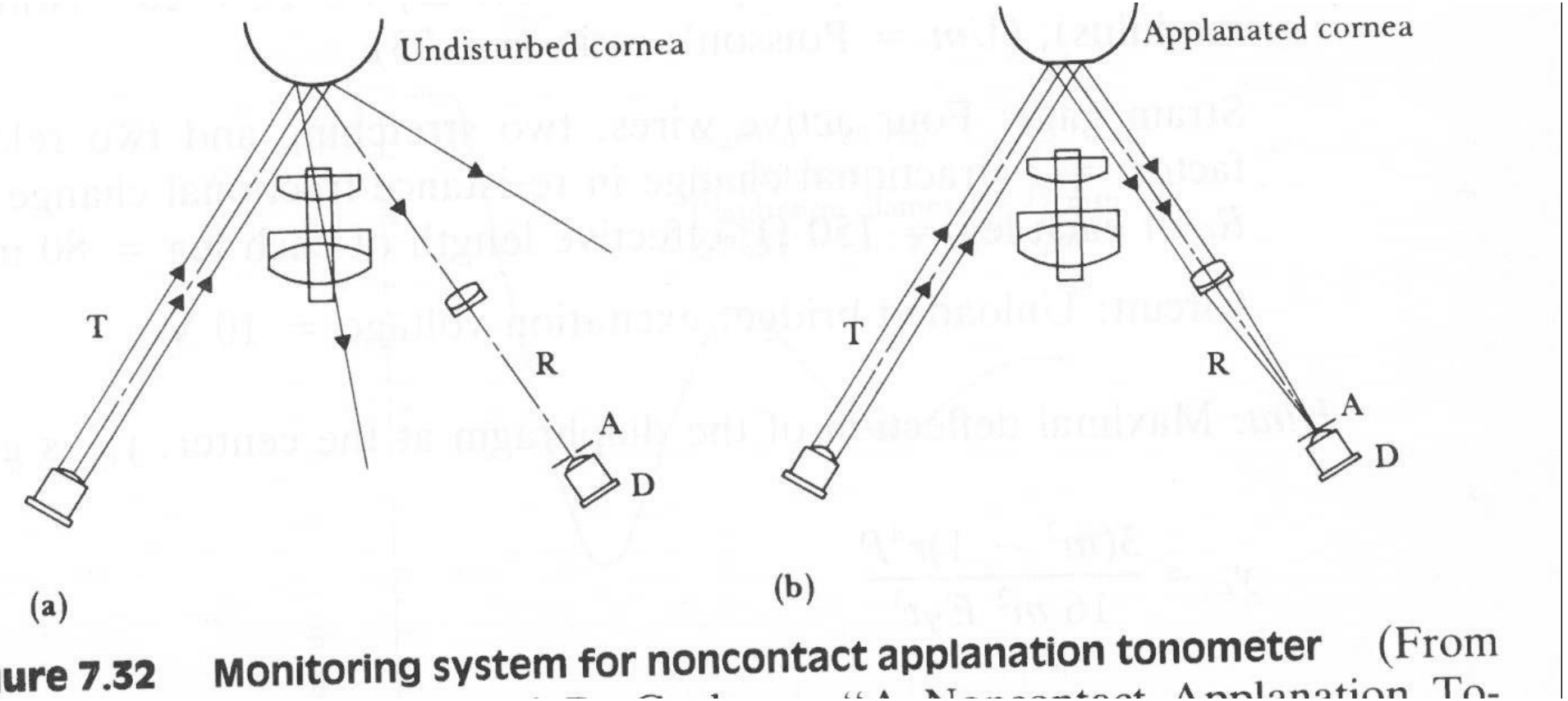


Figure 7.32 Monitoring system for noncontact applanation tonometer (From

Air pulse deforms and flattens central cornea
Collimator A
Linear relationship between intra-ocular pressure and the time interval to applanation

Exercise

Form groups of 2 or 3 students, and discuss:

a. Explain the basic principles of three different ways of measuring intraocular pressure
b. What are the main advantages and disadvantages with each of them?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Case 3



- The intraocular pressure (IOP) was perfectly normal, but the blood pressure remains at pathological levels.



https://www.reviewofoptometry.com/CMSImagesContent/2015/5/044_ro0515_f2-1.jpg

- What is then your most likely diagnosis?

Case 3



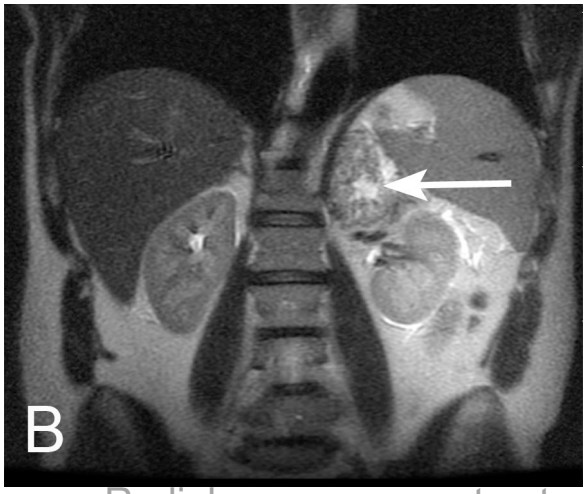
- His heart is examined with ultrasound and angiography, signs of hypertrophy is revealed, but no other indicators that can explain the hypertensive symptoms.

A clue: Some tumours may produce adrenalin-like substanses

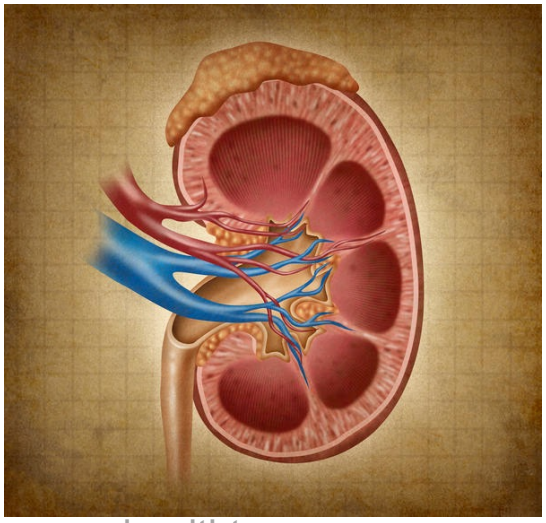
Case 3



- Answer: After a blood sample has been taken, analyses show elevated levels of cathecolamins (nor-adrenaline, adrenaline). This is a distinct indication for Pheochromocytoma, a neurendocrine tumor in the adrenal glands.



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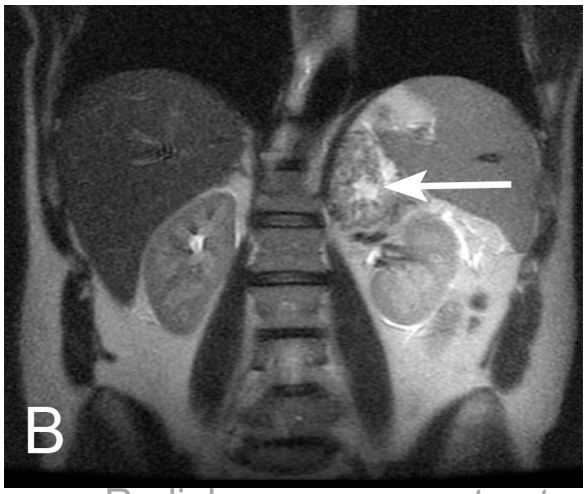
www.healthtap.com

Case 3

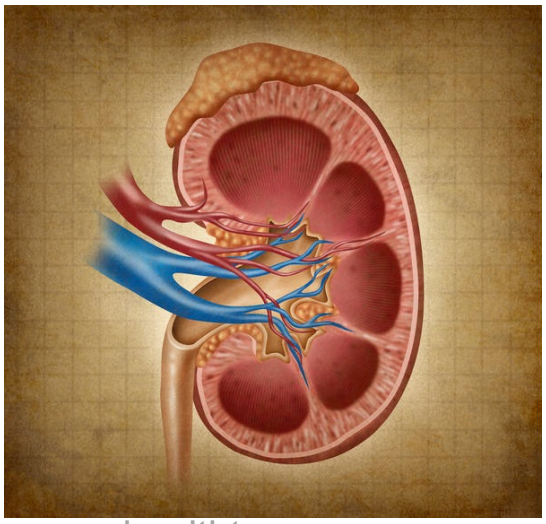


- Prognosis: Pheochromocytoma is benign (godartet) in most cases, and the prognosis is very good if blood pressure related complications are avoided.

- This patient was operated without any side effects or reactions



Radiology, casereport.net



www.healthtap.com