Subject Basics of Technology

Lecturer Mgr. Vladan Bernard, Ph.D.

Tuition 2nd semester

Type of subject Compulsory

Range of education 2 hours

Self-study 28 hours

Type of education Lecture

Completion Oral examination

Course objectives

The course students should be able at the end of: understand and explain the principles and method of devices used in general medicine; to recognize possible risks connected with the use of some medical devices (of mechanical, electromagnetic or optical character, ionizing radiation); to accept rules and methods of safe use of this devices - both in patients and in the healthcare professionals.

Schedule of lectures

1. Medicine and technology. Biosignals and their processing.
2. Conventional X-ray imaging methods.
3. Modern tomographic methods (CT, MRI).
4. Radionuclide diagnostics.
5. Methods and instruments for ionizing radiation therapy.
6. Measurement and registration of temperature.
7. Optical laboratory instruments. Optical diagnostic instruments.
8. Electrodiagnostic methods
9. Ultrasound imaging.
10. Ultrasound doppler and duplex methods.
11. Measurement and registration of mechanical quantities.
12. Methods and instruments used in physiotherapy.
13. Modern physical methods in surgery. Lithotripsy.
14. Artificial body organs.
15. Legislation framework of medical devices.

Study materials

Books:

- Hrazdira, I., Mornstein, V., Bourek, A., Škorpíková, J., Fundamentals of Biophysics and Medical Technology, 2012, ISBN 978-80-210-5758-6
- Davidivits, P., Physics in Biology and Medicine, 2013, ISBN 978-0-12-386513-7
- Mornstein, V., Overview of phisics, 2010,ISBN 978-80-210-5192-8

Web pages:

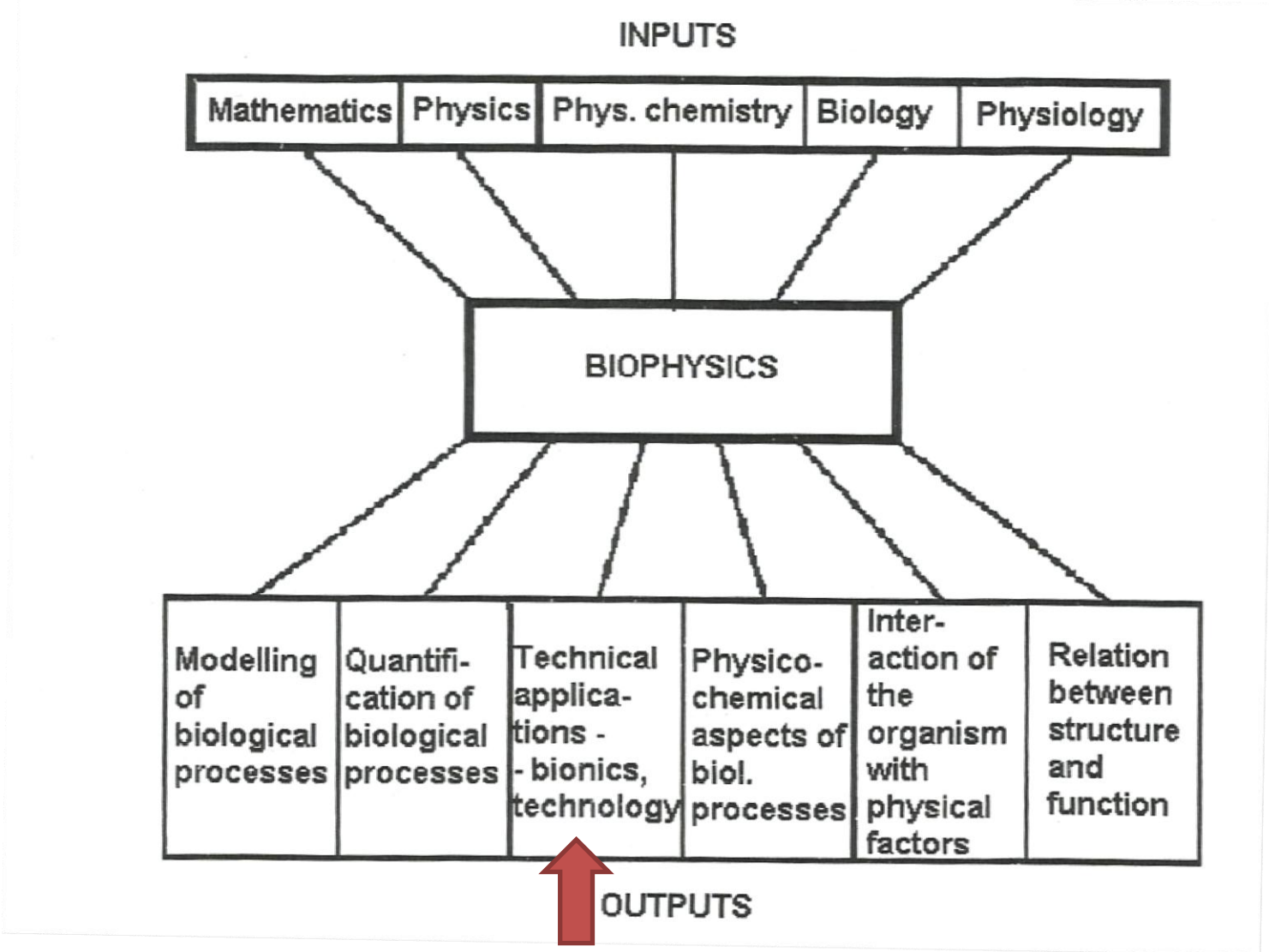
- ww.med.muni.cz (english version → study → lectures)
- http://www.nibib.nih.gov/science-education/science-topics

Web page of Biophysical deparment – study materials

Biophysics

„Biophysics is an interdisciplinary science that applies the approaches and methods of physics to study biological systems. Biophysics covers all scales of biological organization, from molecular to organismic and populations. Biophysical research shares significant overlap with biochemistry, nanotechnology, bioengineering, computational biology and systems biology.“ …wikipedia…

- **Theoretical biophysics** (mathematical interpretation of biological processes)
- **Experimental biophysics** (examine aspect of physical processes in living matter)
- **Applied biophysics** (deals with concrete applications of results of biophisical investigation to different areas of human activity) → **medical biophysics** (biophisical problems related to the human body, human health) → **medical technology and physical methods in medicine**


INPUTS
Mathematics
Physics
Phys. chemistry
Biology
Physiology
BIOPHYSICS
Modelling of biological processes
Quantifi-cation of biological processes
Technical applica-tions - - bionics, technology
Physico-chemical aspects of biol. processes
Inter-action of the organism with physical factors
Relation between structure and function
OUTPUTS

1. Medicine and technology. Biosignals and their processing.

- Definition: a **biosignal** is a human body variable that can be measured and monitored and that can provide information on the health status of the individual. In most cases it is an **electric voltage**.

- Same biosignals ahve mechanical character

Signal processing:

- **measuring** (electrodes, mechanical sensors, cameras)
- **processing** (sampling, analog-digital converter, amplification, filtering)
- **displaying** (analog-digital, print, monitor)
- **archiving** (print, digital)

Types of Biosignals

- **ACTIVE** (body generated) biosignals: the energy source for measurement derives from the patient himself ("internal source")
    - Electrical active biosignals (known as BIOPOTENTIALS) e.g., EKG, EEG, EMG, ERG (electroretinogram) (ERG), EGG (electrogastrogram) etc
    - Non-electrical: e.g., temperature, blood pressure

- **PASSIVE** (body modulated) biosignals: the energy source is from outside the patient ("external source) e.g., X-ray in CT

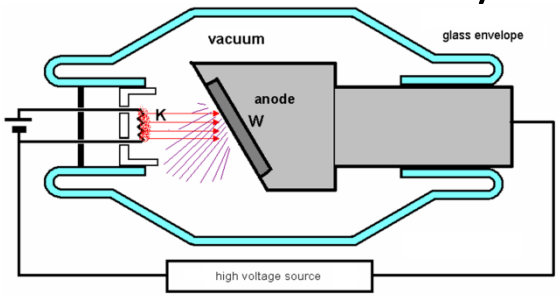
- One, two, three, four dimension (x, y, z, time)

2. Conventional X-ray imaging methods.

- X-ray imaging (XRI) is still one of the most important diagnostic methods used in medicine. It provides mainly morphological (anatomical) information - but may also provide some physiological (functional) information.
- Its physical basis is the different attenuation of X-rays in different body tissues.
- We have to keep in mind that X-rays may lead to serious health effects (e.g., cancer, cataracts) for both patients and healthcare professionals (HCP). Thus, strict legal radiation protection safety measures exist to avoid any unnecessary harm to both patients and the HCP. We will deal with them in a special lecture.

X-ray device

- ***X-ray tube***



- ***Voltage-Current Generator***:
  - High Voltage Transformer – supplies high voltage (up to 150kV)
  - When increasing the magnitude of the electron beam current (by changing the cathode heating) the photon fluence rate (i.e. number of photons per unit area per second) of the X-ray beam increases - however the energy of individual photons does not.
  - The energy of the individual photons can be increased by increasing the voltage between the anode and cathode.
- ***Control panel*** – today most parameters of the device (including voltage and current) are controlled by means of a computer.
- ***Mechanical parts***: tube stand, examination table, grid for removing scattered photons ('Bucky diaphragm'),

- ***X-ray detector***: cassette with radiographic film and adjacent fluorescent screens (in radiography) or image intensifier (both on the way out) or flat panel digital detector (in fluoroscopy or in general).

Interaction with matter (patient)

- X-rays emitted from a small focal area of the anode propagate in all directions. In the tube envelope, some low energy photons are absorbed. Further absorption of these photons occurs in the primary filter, made of aluminium sheet. It absorbs low energy photons which would be absorbed by surface tissues and do not contribute to the image formation (unnecessary patient dose). X-ray beam is delimited by rectangular collimator plates made of lead.

- The rays then pass through the body where transmission or absorption or scattering may occur. After that they pass through the grid, which is in front of the detector to remove scattered photons as these would degrade the image.

- X-ray image is an analogy of a ‘shadow’ cast by a semitransparent and structured body illuminated by light beam coming form an almost point source. The image is formed due to different attenuation of the beam by the different body tissues and by projection of the structures on a film or an electronic X-ray detector

3. Modern tomographic methods (CT, MRI)

- **MRI** is a medical imaging technique used in radiology to image the anatomy and the physiological processes of the body in both health and disease. MRI scanners use strong magnetic fields, radio waves, and field gradients to form images of the body.

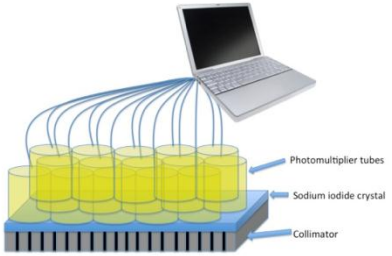
- The term “computed tomography”, or **CT**, refers to a computerized x-ray imaging procedure in which a narrow beam of x-rays is aimed at a patient and quickly rotated around the body, producing signals that are processed by the machine’s computer to generate cross-sectional images—or “slices”—of the body. These slices are called tomographic images and contain more detailed information than conventional x-rays.

Safety aspects

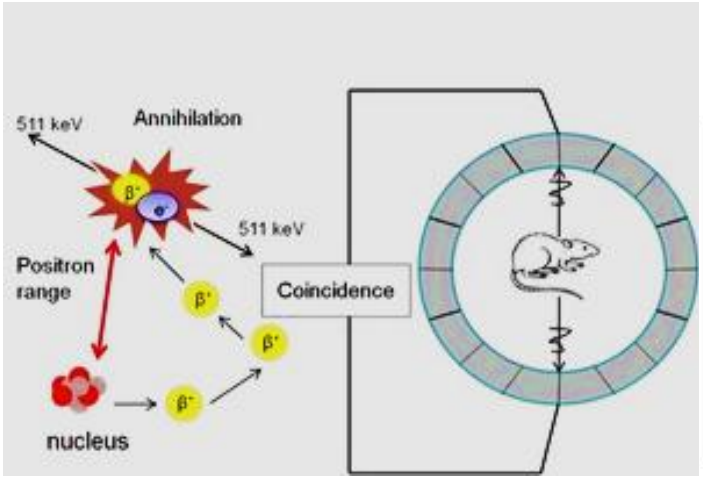
- The magnet can impair function of other medical devices. Hence MRI is strongly contraindicated in patients with some electronic devices inside their bodies (pacemakers, cochlear implants etc.)
- Iron objects are strongly attracted to the "*gantry*" – they can damage the device and cause injuries. MRI is strongly contraindicated in patients with any iron bodies inside (implants, bullets, splinters of grenades etc.)
- MRI is not recommended in the first trimester of pregnancy.
- Some minor problems can be caused by any metals inside the body or on the body surface (heating, prickling sensations). For example: jewellery, some mascaras, old tattoos, tooth fillings, dental crowns and frameworks, implants etc.)
- Some patients are anxious or unquiet inside the device gantry, because of strong noise during the examination. Claustrophobia is also common.

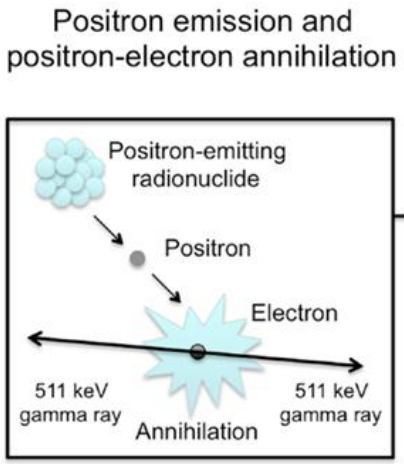
4. Radionuclide diagnostics

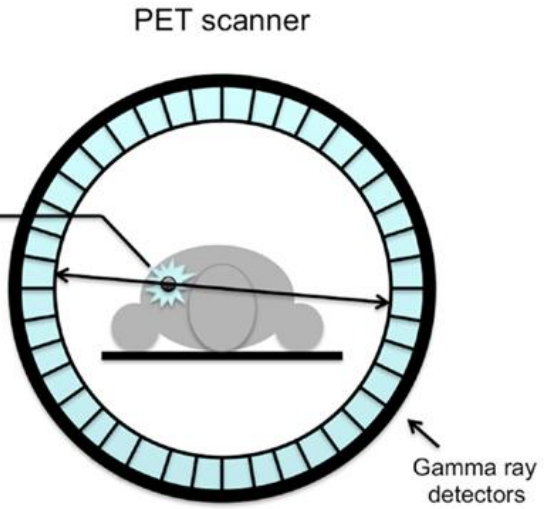
- Scintilation counters
- Gamma camera



- SPECT (Single-Photon Emission Computed Tomography)
- PET (Positron emission tomography)







5. Methods and instruments for ionizing radiation therapy

Radiotherapy

Sources of radiation – radioactive and non-radioactive

Open sources
Closed sources
Brachytherapy - afterloader
Cobalt bomb
Leksell Gamma knife
X-ray tube
Electron accelerators
Linear accelerators
Cyclotrons
Hadron (proton) radiotherapy

6. Measurement and registration of temperature.

- **contact methods**

thermometer

thermocouple

thermistor

liquid crystals

- **contactless methods**

infrared thermometer

infrared thermocamera

7. Optical laboratory instruments.Optical diagnostic instruments.

- **Laboratory instruments**

Microscope, laser, flow cytometry, polarymetry, ***spectrofotometry,*** …

- **Diagnstic instruments**

Mirrors**, *endoscopes, focometer, tonometer*,** perimeter, …

Types of endoscopes, principles of function

Physical law of reflection, Snell law, Lambert-Beer law

8. Electrodiagnostic methods

- Basic physical quantity – el. voltage, el. Potential, resistance, impedance
- Principles:
- origin of signals (polarisation/depolarisation)
- detection (type of electrodes)
- processing (amplifier, displaying)

- …graph - device, …gram – graph, graphic presentation

- **EKG** (electrocardiograms) – electrodes, leads, graph
- **EEG** (electroencefalograms) – electrodes, types of signals, graph
- **EMG** (electromyograms) – electrodes, graph

9. Ultrasound imaging.

- Physical description of ultrasound (frequency, spreading, attenuation , velocity ...)
- Haw to produce ultrasound (piezoelectric, magnetostrictive effect)
- Echo, acoustic density

Types of ultrasound imaging:

A mode (aplitude)

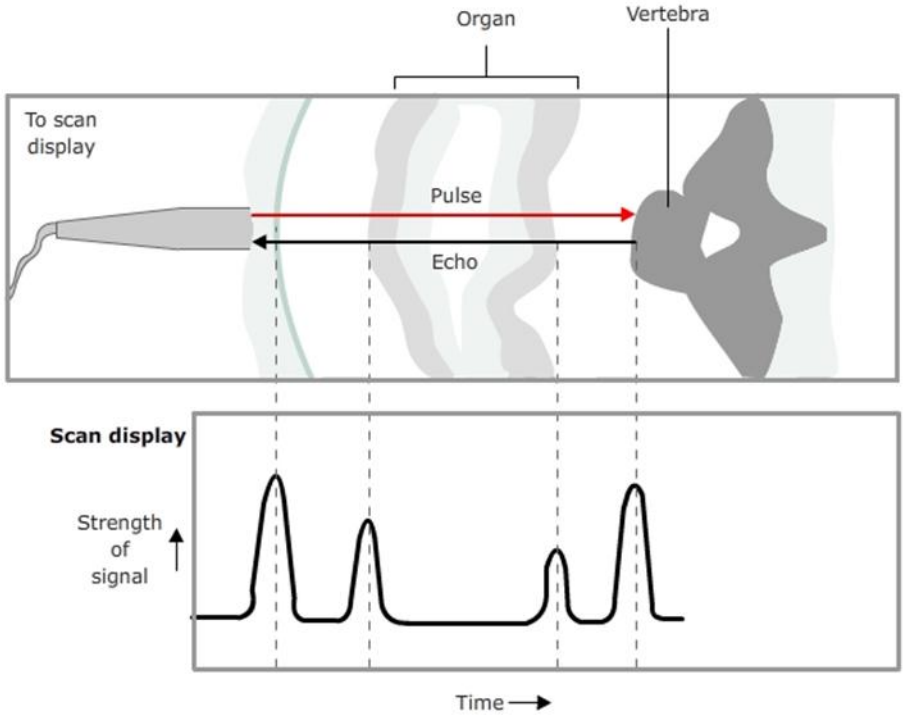
M mode

B mode (brightness, static / dynamic)

3D,4D ultrasound

Echocontrast agents

A-mode


Organ
Vertebra
To scan display
Pulse
Echo
Scan display
Strength of signal
Time

B-mode


MEDISON
Abdomen
#255 16.0cm
CN2-8 HGen.
[2D] G50 / P90 /125dB
FA6 / FSI1 / PGC0
MI0.8 / TIs0.2
0
5
10
15

10. Ultrasound doppler and duplex methods.

- **The Doppler effect** (frequency shift of waves formed or reflected at a moving object) can be used for detection and measurement of blood flow, as well as, for detection and measurement of movements of some acoustical interfaces inside the body (foetal heart, blood vessel walls)

1) Systems with **continuous wave** – CW. They are used for measurement on superficial blood vessels. High velocities of flow can be measured, but without depth resolution. Used only occasionally.

2) Systems with **pulsed wave** – PW. It is possible to measure blood flow with accurate depth localisation. Measurement of high velocities in depths is limited.

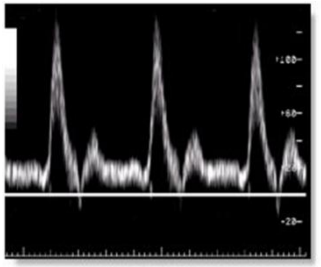


Figure 2

PW

Colour Doppler imaging

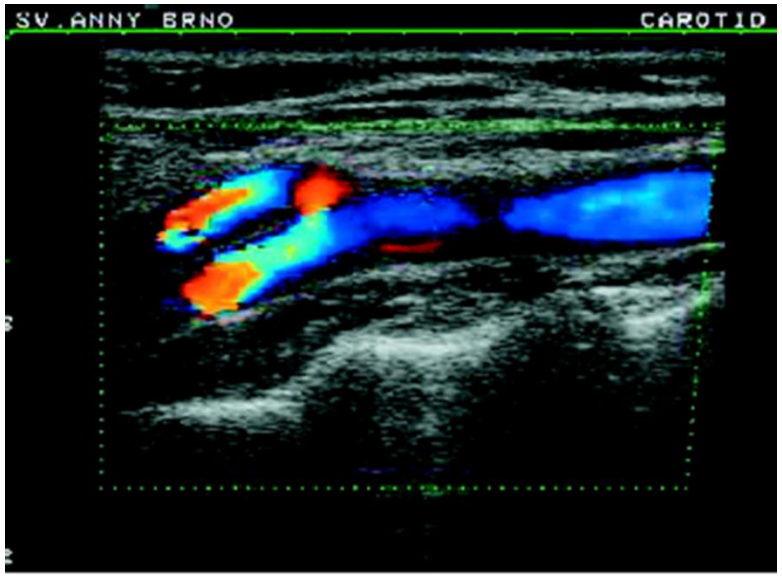
BART rule – blue away, red towards. The flow away from the probe is coded by blue colour, the flow towards the probe is coded by red colour. The brightness is proportional to the velocity, turbulences are depicted by green patterns.

DUPLEX method is a combination of dynamic B-mode imaging (the morphology of examined area with blood vessels is depicted) and the PW Doppler system (measurement of velocity spectrum of blood flow).

TRIPLEX method

A combination of duplex method (B-mode imaging with PW Doppler) and colour flow mapping

Colour doppler



Triplex method

11. Measurement and registration of mechanical quantities

- **Blood pressure** – direct (catheter), undirect (Riva-Rocci method, Korotkoff sound, tonomether, usin of doppler device)
- **Mechanical work and power of heart** ($W=p.\Delta V$)
- **Spirography** (velocity, volume, …)

12. Methods and instruments used in physiotherapy.

- Main methods of physical therapy:

- Therapy by mechanical treatment
- Non-electric thermotherapy – (heating and cooling, hydrotherapy)
- Electrotherapy
- Ultrasound therapy
- Magnetotherapy
- Phototherapy

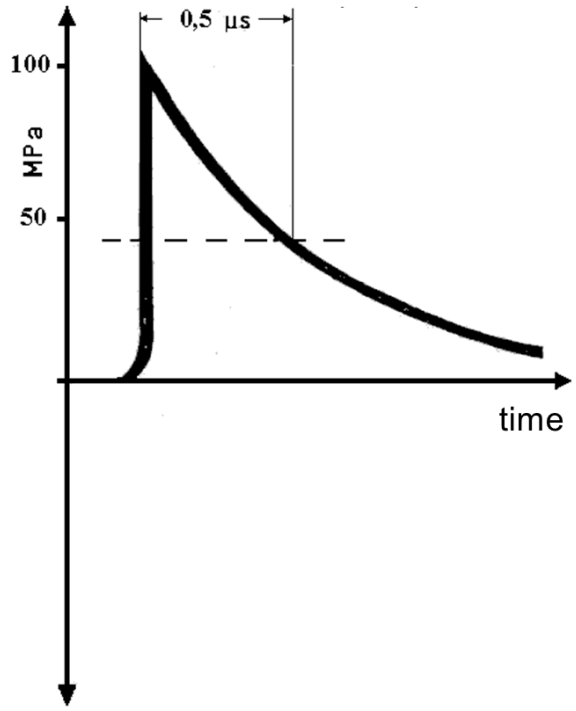
- safety aspects of use of electric currents

13. Modern physical methods in surgery. Lithotripsy.

- Laser
- Radiofrequency abblation
- Nanoknife
- Cryocauter
- Focused ultrasound wave
- …

Lithotripsy – principles, devices, what is shock wave (shock wave is not ultrasound wave!!!)

- extracorporeal shock-wave therapy (ESWT)
- intracorporeal shock-wave therapy (ISWT)



14. Artificial body organs.

- Support and replacement of heart
- Cardiopulmonary bypass (bubble oxygenators, membrane oxygenators)
- Mechanical ventilation of lungs
- Artificial kidney – haemodialysis, peritoneal dialysis
- Insulin pumps
- Bone implant
- Cochlear implant
- Dental prostheses
- …

15. Legislation framework of medical devices

- **ALARA principle** - The ALARA principle is that the residual risk shall be as low as reasonably achievable.

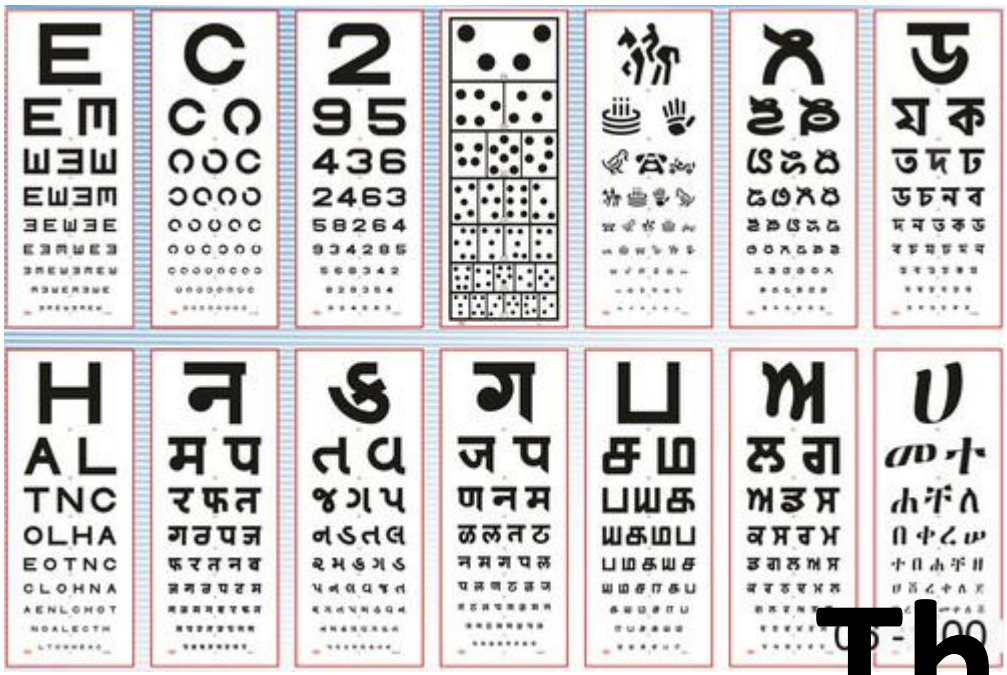
- hygienic standards

Ionizing radiation

Lighting

Norms, laws, … (depending on country, type of device, internal hospital rules, …)

Certification, training of personnel, audition, …



Thank you

Have a nice day!

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