DENTO-MAXILLARY RADIOLOGY AND IMAGING

Course 1

CLASSIC DIAGNOSTIC RADIOLOGY

1.1. HISTORY

Classical radiology use a cone beam of x-rays for image acquisition being the first imaging technique available in modern medicine.

An x-ray beam passing through the patient is decreased (attenuated) being absorbed according to the density and atomic number of the various tissues, the resulted x - ray beam is then projected on a radiographic film - radiography or on a fluorescent screen - dynamic fluoroscopy.

Wilhelm Conrad Roentgen, a german physicist, is credited as the discoverer of X-rays in 1895, because he was the first who systematically study them, though he is not the first to have observed their effects.

He gave them the name "X-rays" (signifying an unknown quantity) and since then many others referred to these as "Röntgen rays" (and the x - ray radiograms as "Röntgenograms")

He was awarded the Nobel Prize in Physics in 1901 for this epochal discovery.

X-rays were found emanating from Crookes tubes invented around 1875, by scientists for cathode rays investigation.

Röntgen was investigating cathode rays using a fluorescent screen painted with barium platinocyanide and a Crookes tube which he had wrapped in black cardboard, so that the visible light from the tube would not interfere.

He noticed a faint green glow from the screen, about 1 meter away and so Röntgen realized that some invisible rays coming from the tube were passing through the cardboard to make the screen glow.

He discovered its medical use when he made a picture of his wife's hand on a photographic plate formed due to X-rays, the photograph of his wife's hand being the first photograph of a human body part using X-rays.

Very soon scientists discovered on their own bodies that x-ray produce biological damage: can destroy living tissue and can cause severe skin burns - radiodermatites - anemia or can induced malignancy.

This destructive power is used in oncology as X-ray therapy to destroy tumoral cells.

In 1936 a monument for the victims of the X-ray radiation was raised on the grounds of the Asclepius St. Georg's hospital in Hamburg.

The Bucky-Potter antiscattered grid - a protective device to block scattered x-rays - invented by German radiologist Gustav Bucky in 1913, composed of alternating strips of an x-ray absorbent material - lead - and an x-ray transparent material - aluminum - positioned on the opposite side of the patient from the x-ray tube to reduce the quantity of scattered x-ray. It was improved by American radiologist H.E. Potter in1920 who eliminate grid lines by moving the grid at right angles to the grid lines during the exposure.

Classical Radiology appear early in Romania due to the fact that in the early 1896 Romanian physicist Hurmuzescu worked with professor Benoit and professor Gheorghe Marinescu (Charcot team) in Sorbonne laboratory - returned home they promote medical radiology in Romania - first radiographies were achieved at Colţea hospital in professor Severeanu surgical department in the same year, 1896.

The first Romanian radiologist was Dimitrie Gerota which led the Colţea hospital radiology laboratory from the year 1899.

1.2. PHYSICS

1.2.1. NATURE AND PRODUCTION OF X-RAYS

X - Rays are highly penetrating, invisible rays, belonging to the general category of electromagnetic radiation, useful wavelength ranging in radiography at about 0.1 to 0.5 Angstrom (crest to crest), which is corresponding to energies of 123 to 25 keV.

As all electromagnetic radiation including light, x-rays behave both as waves and as particles (photons), a beam of x-rays is considered as a beam of high frequencies photons moving in a wavelength.

X - Ray photons carry enough energy to ionize atoms and disrupt molecular bonds, being considered as ionizing radiation, harmful to living tissue.

A very high radiation dose over a short amount of time causes radiation sickness, while lower doses can give an increased risk of radiation-induced cancer.

In medical imaging this increased cancer risk must be outweighed by the benefits of the examination.

The ionizing capability of X - rays is utilized to kill malignant cells using radiation therapy and it is used for material characterization in X-ray spectroscopy.

In a Coolidge tube the electrons liberated by thermo - ionic effect from a tungsten cathode filament heated by an electric current and accelerated by a high voltage towards the anode collide with the atoms and nuclei of the metal anode target and produce a small amount of X - rays, 99 - 98 percent of the incident electron's kinetic energy being converted to heat.

X - Rays produced when the electrons are suddenly decelerated upon collision are commonly called bremsstrahlung or "braking radiation“.

The bombarding electrons with sufficient energy can knock an electron out of an inner shell of the target metal atoms and electrons from higher states drop down to fill the vacancy, emitting X - ray photons with precise energies called characteristic / fluorescence X - rays.

So, the emitted x-rays beam is composed of two kinds of radiations:

- **"Braking radiation“, produced by deceleration of the electrons, with a continuous spectrum and a smooth, continuous curve, independent on target material used in radiology;**
- **Characteristic / fluorescence X - rays, produced by electrons interactions with the electrons of the material target, having spikes characteristic with K lines target material used in spectroscopy.**

The emitted x - rays beam is a sum of braking and characteristic radiations being defined qualitative by penetrability and quantitative by intensity.

"Quality" refers to the energy of the photons of X - ray beam giving the penetrating ability and increases in direct proportion by higher accelerating voltage of electrons beam to the anode measured in kV.

"Quantity" or intensity refers to the number of photons of X - ray beam and increases indirect proportion to increases in quantity of electrons liberated by thermionic effect from the tungsten cathode filament and yet by increasing the intensity of heating electric current measured in mAs.

1.2.2. INTERACTION OF X - RAYS WITH MATTER

Photons of X - ray beam projected on matter can pass through the spaces between nucleus and electrons or can interact with electrons of the atoms.

Magnifying 1836 times an atom their nucleus will be of a football ball size, electrons as a pea grain and the distance between them will be 23 kilometers.

As an X - ray beam passes through a body, three possible fates await each photon from the incident radiation:

1. **- It may penetrate the section of matter without interacting;**
2. **- It may interact with the matter and be completely absorbed by depositing its energy;**
3. **- It may interact and be scattered or deflected from its original direction and deposit part of its energy.**

ATTENUATION

It's the reduction in intensity of an X-ray beam as it passes through an object due to the absorption and scattering of photons.

The amount of attenuation that occurs depends on the intensity of the original X - ray beam and the physical properties of the object through which the X - ray beam passes, each tissue having a specific attenuation coefficient used in Computed tomography for image reconstruction.

ABSORPTION

It's the quantity of X - ray absorbed as the X - ray beam passes through matter.

Absorption depends on some factors which according to Bragg-Pierce relation are:

Absorption = $Z^4 \times \lambda^3 \times \rho \times d$

where:

z = the atomic number of the element,
λ **= the wavelength,**
ρ **= density,**
d = thickness.

1.2.3. X-RAYS PROPERTIES

COMMON ELECTROMAGNETIC RADIATION PROPERTIES:

1. **- Propagation and speed. X - rays travel in straight lines, diverging from the focus only at the same speed of light: 3 x10^8 meters/sec. or 186,000 miles/sec. in a vacuum;**
2. **- Divergention - X - ray intensity is inversely proportional to square distance;**
3. **- Reflection;**
4. **- Refraction;**
5. **- Diffraction;**
6. **- Polarization.**

PROPERTIES DERIVED FROM INTERACTION WITH MATTER:

1. **- Penetrability;**
2. **- Attenuation;**
3. **- Absorption;**
4. **- Fluorescence - can cause some substances to fluorescence;**
5. **- Chemical and biologic changes, mainly by ionization and excitation.**

1.3. PRINCIPLES AND LAWS OF PLAIN FILM RADIOGRAFIC IMAGE CREATION

The radiographic image is created according to optical radiological laws:

1. **- Cone x - beam projection law;**

2. - Tangential incidence law;
3. - 5 radiological densities law;
4. - Summation and subtraction laws;
5. - Parallax law;
6. - Shadow law.

1. - CONE X - BEAM PROJECTION LAW

The X - ray beam is projected as a cone with the apex in the focus of the X - ray tube and the base on the film plane.

The closer the focus is, the more magnified the image of the object.

The closer the film is, the image of the object gets its natural size.

The radiographic image is distorted if the object is in oblique position in the X - ray beam and is normal if it is perpendicular.

2. - TANGENTIAL INCIDENCE LAW

The image has sharp margins if the X - ray beam is tangential to the surface of an opaque object or when it reaches the surface between two different opacities.

When a X - ray beam passes longitudinally through a tubular structure the resulting image is round orthograde.

3. - THE FIVE RADIOLOGICAL DENSITIES LAW

A radiographic image is composed of a ''map'' of X - rays that have either passed freely through the body or have been variably attenuated (absorbed or scattered) by anatomical structures.

According to Bragg - Pierce relation:

$$\text{Absorption} = Z^4 \times \lambda^3 \times \rho \times d$$

the denser the tissue, the more X - rays are attenuated. For example, X - rays are attenuated more by bone than by air containing lungs.

Contrast within the overall image depends on difference in both the density of structures in the body and the thickness of those structures.

According to Bragg - Pierce relation:

$$\text{Absorption} = Z^4 \times \lambda^3 \times \rho \times d$$

the greater the difference in either density or thickness of two adjacent structures leads to a greater contrast between these structures.

According to Bragg - Pierce relation:

$$\text{Absorption} = Z^4 \times \lambda^3 \times \rho \times d$$

Upon the Z atomic number and ρ density, there are five different densities that can be useful to determine the nature of an anatomical structure:

- **metal,**
- **bone**
- **soft tissue (except fat) and body fluids,**
- **fat,**
- **air and gas.**

THE FIVE RADIOLOGICAL DENSITIES LAW: METALS

Metallic restoration, metallic implants, prosthesis…due to high Z atomic number and high density absorbed all quantities of the X - rays from the incident beam and no radiations reached the plain film.

There is no reducing process of the tiny silver Bromide crystals, so the adjacent film remains white - radiopaque -

THE FIVE RADIOLOGICAL DENSITIES LAW: BONES

Have the following degree of absorption in descending order: enamel, dentin, cementum, compact bone, cancellous bone.

Also due to high Z atomic number and high density absorbed almost all quantities of x - rays from the incident beam and almost no radiations reached the plain film.

There is almost no reducing process of the tiny silver Bromide crystals, so the adjacent film remains in varying degrees of white - radiopaque -

THE FIVE RADIOLOGICAL DENSITIES LAW: SOFT TISSUE (EXCEPT FAT) AND BODY FLUIDS

Muscles, tendons, parenchyma, vessels, body fluids…due to small Z atomic number (C, O, H, N) absorb a smaller quantities of X - rays from the incident beam than bones do and some radiations reached the plain film according to their density and thickness.

There is some reducing process of the tiny silver Bromide crystals to silver ions that blackened the film in varying small degree, so the adjacent film appeared in varying degree of grey - still radiopaque -

THE FIVE RADIOLOGICAL DENSITIES LAW: FAT

Absorb a ten times smaller quantities of X - rays from the incident beam than soft tissue do and radiations reached the plain film fine contrasting muscles and organ parenchyma.

The adjacent film appeared with some radiolucency of fat surrounding muscles and organ parenchyma radioopacities.

THE FIVE RADIOLOGICAL DENSITIES LAW: AIR AND GAS

Have a thousand times smaller density than soft tissues so absorbing very few of X - rays from the incident beam than soft tissues do and almost all radiations reached the plain film and the adjacent film appeared radiolucent.

4. - SUMMATION AND SUBTRACTION LAWS

The radiographic image is a sum of all anatomic structures images obtain as X - ray beam passes through and have been projected in a single plan.

If the anatomic structures are radiopaque summation is positive and we'll have a greater radioopacity and if there are some radiolucent structures summation is negative, the image losing some radioopacity by subtraction.

5. - PARALAX LAW

In a direct projected radiographic image of a summated anatomic structure by moving the tube we obtain an oblique projection allowing us to differentiate the summated structures: the more moving structure is the closest one to the X - ray tube and will be projected separately aside.

6. - SHADOW LAW

Define the quality of a radiographic image which are sharper if the focus of the X - ray tube is as small as possible - as a dot -

If the focus of the X - ray tube is larger the image will be surrounded by an area of semi - darkness.

1.4. IMAGING TECHNIQUES AND MODALITIES

1.4.1. EARLY CLASSICAL RADIOLOGICAL EXAM - DIRECT ANALOGUE

They are the first imagined radiological modalities in which the final image is form by projection of the X - ray beam directly on the detector medium (fluorescent screen or photographic film) with no other device interposing, being also very irradiating.

TRADITIONAL FLUOROSCOPY or screening in which the transmitted x-ray beam fell on a fluorescent screen resulting in a dynamic projection light image observed directly by the radiologist who requires: heavy lead equipment protection required and 30' dark eyes adaptation.

THE EARLIEST RADIOGRAPHIC EQUIPMENTS where the x - rays after having passed through the patient form an image directly on a photographic film by reducing the tiny silver bromide crystals to silver ions that blackening in varying degree create an image, a risky method due to highly radiation dose needed.

1.4.2. MODERN RADIOGRAPHIC EQUIPMENT - INDIRECT ANALOGUE

These were imagined in order to offer a considerable reduction in radiation dose according the ALARA law (As Low As Reasonably Achievable) - radiation protection of patient and personnel by reducing somatic and genetic doses to a level as low as possible to achieve an image of diagnostic value.

RADIOGRAPHIES are done with a reduced dose of radiation by using a cassette where the film is lying between two intensifying screens (fluorescent screen).

INDIRECT FLUOROSCOPY which also used a reduced dose of radiation due to an x-ray intensifier connected to a television system, the dynamic X - ray exam being done in the day light and with the radiologist in the other room manipulating from the distance the X - ray unit.

1.4.3. MODERN RADIOGRAPHIC EQUIPMENT - DIGITAL

RADIOGRAPHIES are done with a highly reduced dose of radiation on a phosphorous digital image plate, read by a laser beam and transformed in emitted light, also in turn transformed in electronic signal by a photo multiplier and then amplified, digitized and transferred to an image processor which calculate an optimal image that is transmitted to a laser printer / Picture Archiving and Communications System (PACS) / is copied on a CD/DWD.

FLUOROSCOPY uses a digitized analogue video signal coming from x - ray intensifier - television system and displayed on a TV monitor.

Modern current radiographic equipment can achieve images from patient standing, sitting or lying down, with the x-ray tube able to be angled as required.

1.5. LESIONAL PLAIN FILM SEMIOLOGY

If there is an unexpected increase or decrease in the density of a known anatomical structure then this may help determine the tissular structure of the abnormality: the lesion will appear as an unexpected radioopacity / radiolucency / mixed image over the normal image of the investigated anatomical structure.

1.6. RADIOPROTECTION

X - rays diagnostic exams imply the exposure to radiation of not only the patient but also of the radiologist doctor and of the technical and medical staff.

In order to avoid biological harmful effects in professional radiation exposure our legislation recommend a so called maximal tolerance radiation dose for implied staff:

- **0.1 rem/week;**
- **5 rem/year;**
- **50 rem till 30 years of age;**
- **200 rem for a holly life.**

Radiation exposure dose is determined by dosimetric measurement with radiographic films or ionizing chambers.

The radiation dose can be described as the energy absorbed from the X - rays beam used in an imaging procedure and more precisely the energy absorbed by an object divided by the mass of the object.

The modern unit of absorbed dose is the grey (abbreviated as Gy), 1 grey being equal to 1 joule (J) per kg. An older unit of absorbed dose is the rad, where 100 rads are equal to 1 Gy.

The biologic unit of measure for human is the rem (Roentgen equivalent man) which correspond to the biologic effect of a radiation dose that by absorption produce a biologic action equal to a dose of 1 Roentgen, in international unit system, the effective dose unit is the Sievert (Sv), 1 Sievert being equal to 100 rems.

The Roentgen is the X - rays measure unit being equal to the quantity of X - rays that in physical normal conditions produce a number of 2.1 x 10^{10} ions pairs with electric charge of 1 franklin in 1 cm^{3} of air.

The dose of exposed population must not exceed 150 mrem/year.

The protection of examined patients implies: reduction the duration of an exam to a time as short as possible, reduction in radiation dose according the ALARA law to a level as low as possible to achieve an image of diagnostic value, gonads and thyroid gland coverage during a radiographic procedure, specific protective measures in women, the use of the intensifying screens and of the film processing machines.

In children the X - rays exams must be carefully and judiciously indicated with avoiding the fluoroscopy and the sternum and gonads protection.

The CT - scan, using also the X - rays, implies from these reasons the same measures of protection and a carefully and judiciously indication due to the fact that radiation dose range from 15 - 50 mGy, being at least 10 times higher than in radiographic exams. In order to these reasons it is necessary to optimize scan parameters to minimize patient dose consistent with diagnostic image quality: minimize mAs and kVp, maximize pitch, slice thickness and collimator setting. In children it is mandatory to reduce the radiation dose by using pediatric protocols of CT - scanning in which the CT scan parameters are reduced according to patient size.

In order to avoid the exposure of population to X - rays the Roentgen units must be placed in rooms isolated from lounges, offices, medical consulting and treatment rooms.

The walls of the rooms must have plaster with barite, covered with barium containing paint, the doors padded with lead sheet and generally avoid any inner reflecting ceramic object.

The Roentgen unit must be placed in a room with a surface of at least 12 m^{2} the radiogenic focus being situated to at least 1.5 m distance from the walls.

1.7. DENTO - MAXILLARY RADIOLOGY HISTORY

1.7.1. DENTAL SEGMENTS RADIOGRAPHIES

Dental radiographic investigation was initiated by Walkhoff in Germany at about 15 days after X - rays discovery and followed by others in France and England in the next few years.

In 1899 at Stockholm, Sjöegren succeeded to achieve better images by retro alveolar positioning of photographic paper.

In 1907 Belot in France, Holtznecht şi Kinbock in Austria, Costa Sinclaire in England, grounded an endooral isometrique and orthoradial technique using a glass cassette held by patient in occlusion, with an X - ray beam angulation between 45˚-60˚.

The introduction of nitrocellulose base film discovered by Eastman Kodak in medical radiographic practice was a true revolution in medical dental diagnosis.

Dieck has developed the parallel plans technique with a retroalveolary film held by patient, discovered in 1907 by Cieszinsky, grounding the retroalveolary, isometrique and ortoradial radiographic incidence.

Simson has developed in 1930 axial radiographic incidence with film held by patient in occlusion.

D. Gerota which led the Colţea hospital radiology laboratory made in Romania the first dental radiography in 1901.

From 1921 dental radiology has been teached as an improvement course at the Colţea hospital radiology laboratory.

1.7.2. ORTHOPANTOMOGRAPHY

It's a panoramic X - ray scanning of the upper and lower jaw which shows a two - dimensional view of a half - circle from ear to ear.

The method uses the technique of classic linear tomography: images of multiple planes are taken to make up the composite panoramic image, where the maxilla and mandible are in the focal trough and the structures that are superficial and deep to the trough are blurred.

It was initiated in Japan by Numata in 1933 and developed in Helsinki by Paatero in 1947 that is considered the father of orthopantomography.

Latter, in 1964, Tomisaalo and Niemenen developed Paatero's technique.

1.7.3. SIALOGRAPHY

It's the radiographic examination of the salivary glands.

Usually the exam involves the injection of a small amount of contrast medium into the salivary duct of a single gland, followed by routine X - ray projections regional radiography.

The method was invented in 1925 by the Romanian professors Iacobovici, Popliţa, Jianu and Albu.