ORIGINAL RESEARCH PAPER

Medicine

PRINCIPLES OF X-RAY TECHNOLOGY IN MEDICAL IMAGING AND IMPROVEMENT OF RADIOLOGICAL IMAGES

KEY WORDS: Education, X-ray tube, X-rays, Ionization (Ionization) Radiation , X- ray Radiologists & Radioprotection Protection, Medical Instruments Technologists, X-ray Departments Nurses, X-ray Department Doctors

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ABSTRACT

The X-ray tube is one of the most important components in any X-ray system. In the beginning, physicists and physicians used gas ion tubes. The so-called Coolidge tube applied a high vacuum and is still used today. Medical examinations have required continuously improved designs of X-ray tubes (smaller focal spots at a higher output). The principle of the Goetze line focus is still applied in any diagnostic X-ray tube. Different anode materials and the rotating anode contributed to an increased output and reduced exposure time. Bearings needed special attention. Spiral groove bearings are the most advanced design today. The heat storage capacity of the anode and the tube housing assembly influences examination time and patient throughput. Cardiac imaging required less motion blurring in cine film images and increasing radiation exposure in interventional procedures calling for measures to reduce dose. Protection against radiation and electric shock has always been a concern of design engineers. Focal spot sizes dedicated to specific applications and heat management within the total tube housing assembly will be future issues. Even in the event of ultrasound and MR technology, X-ray procedures will still be applied for diagnostic and interventional purposes.

Ionizing are rays that carry energy capable of penetrating matter, causing ionization of atoms, violently breaking chemical bonds, and causing biological damage to the human body.

The ionization of a neutral atom is the violent removal of an electron from its layer due to an external cause, resulting in the production of two oppositely charged ions, the positive atom and the negative electron.

The best known ionizing radiations are the X - rays widely used in medicine, as well as the á , â , and ã radiations emitted by the unstable nuclei of atoms.

Radiation a: Particle radiation consisting of two protons and two neutrons. It has low penetration and can be cut from a sheet of paper. It is difficult to detect and poses a significant risk of internal exposure.

Radiation â: Particle radiation consists of negatively charged electrons or positively charged positrons. It is more penetrating than á-radiation, but can be cut from plastic sheets or thin metal sheets. It poses a risk of external eye and skin exposure and a risk of internal exposure. The degree of detection depends on the energy of the â particles.

X or ã radiation : Electromagnetic energy radiation capable of causing ionization. Steel, lead, or concrete (or a combination) needs to be used for shielding. It is much more penetrating than â radiation and poses a risk of external and internal exposure. It can be detected more easily by á and â radiation.

1. Electromagnetic field / spectrum

When we say, electromagnetic radiation, particularly means the energy spread (radiated) by the electromagnetic waves, to which in turn consist of an electric field and a magnetic field (electromagnetic field), the which move simultaneously and perpendicularly to each other, by a source where the produce in every direction in space without needing a propagation medium, as eg with the sound waves.

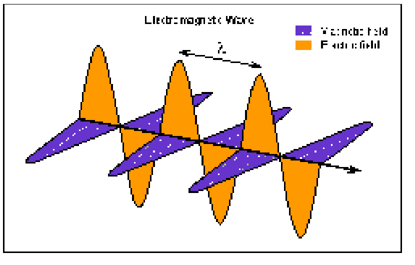


Figure 1. The electromagnetic field.

A common feature of all electromagnetic waves is the speed of 300,000 kilometers per second, while that of differentiating frequency (or wavelength). The frequency is practically the number of waves that pass through a certain point and per second, while it is identical to the frequency with which a dipole beats, which is also the cause - source of the electromagnetic wave. Generally, any oscillation of electric charge causes the production of electromagnetic waves of the same frequency. The frequency, measured in Hertz (1Hz = 1kyklos per second) and THE multiples kHz (= 1000 Hz, kilocycles per second), MHz (= 1,000,000 Hz, megahertz per second) and GHz (= 1.000.000.000Hz) It is the size whereby tHE electromagnetic waves are classified in different classes, starting from the industrial and telephone waves of low frequency, produced by moving electric charges (electric current) to the hard X-rays and y very high frequencies, generated by redistribution of the building blocks of matter, as shown in the figure below. The sum of these frequencies constitutes the so-called electromagnetic spectrum.

1.1. Radiation

The term radiation describes the propagation of energy in space either in the form of particles (eg electrons) or in the form of waves (eg radio waves).

We coexist with radiation throughout our lives, as we are surrounded by a large set of natural and artificial sources of radiation. With our senses, we perceive only a very small area of the spectrum of radiation: visible light through sight and infrared radiation through heat. Their world began to be perceived in the last century, due to the development of artificial means of detecting them.

Natural sources of radiation are natural radioisotopes which are found in the soil and subsoil, in the air, in water and exist from the formation of the earth. The natural source of radiation is the sun, but also the cosmic radiation emitted by celestial bodies.

Artificial sources of radiation are radiation production machines, e.g., machines used in medical applications, lamps, radar, antennas, etc.

Radiation is characterized by its wavelength or frequency and the energy it carries. Depending on its energy and the effects it induces on matter, radiation falls into two broad categories: ionizing radiation and non-ionizing radiation.

Radiation is called ionizing when it has energy capable of penetrating matter and causing ionization of its atoms. X-rays, gamma rays, electrons, protons, neutrons are ionizing radiation.

When radiation carries relatively low energy, which can not cause ionization of matter, it is called non-ionizing. However, the energy carried by non-ionizing radiation is capable of causing electrical, chemical, and thermal effects on matter. Non-ionizing is the radiation that covers the spectrum from low frequency electric and magnetic fields to ultraviolet radiation.

Radiation affects the body in a complex way, sometimes beneficially and sometimes harmfully, depending on the species, its intensity, and the energy it carries.

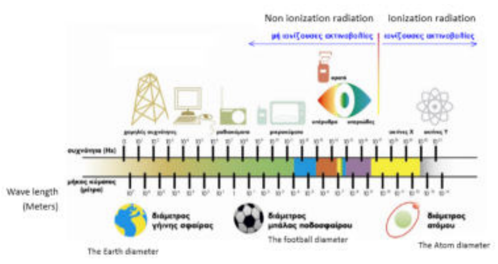


Figure 2. The electromagnetic spectrum

Figure 3. Ionizing and non-ionizing radiation.

2. X-ray production

X-rays are produced when electrons (thermoelectrons) with high kinetic energy interact with matter and convert their energy into electromagnetic radiation. The X-ray tube consists of an electron source (cathode), a space for the accelerated motion of electrons in a vacuum, a target electrode (anode), and an energy source for electron acceleration. X-ray beams for medical imaging are produced by X-ray diagnostic lamps.

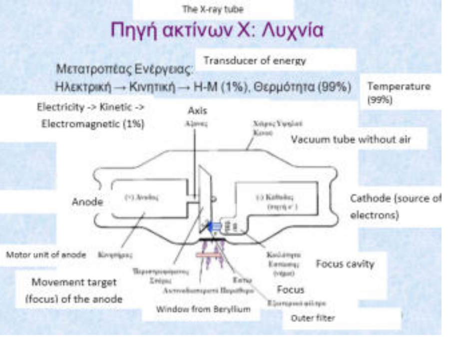


Figure 4. X-ray tube structure.

In detail, an X-ray tube consists of:

1) The cathode where the electron beam is produced.
2) The high vacuum space where electrons are accelerated.
3) The anode where the X-ray beam is produced.
4) The glass shell that surrounds the lamp and is properly shielded with a lead housing.

The lamp is properly shielded (so that X-rays only come out of the special window) and equipped with cooling systems. Special guides shape the geometry of the outgoing beam and special filter filters shape the quality (energy) of the outgoing electromagnetic radiation. The generator is the energy source for the operation of the lamp and it regulates: (a) the value of the potential difference that will accelerate the electrons (energy), (b) the value of the current that determines the number of photons produced (intensity) and (c) the exposure time.

The lamp is essentially two electrodes at the ends of an air vacuum tube, which receive a large potential difference (kV) to accelerate the electrons. The cathode is negatively charged and acts as a source of electrons. The anode is positively charged and acts as a suitable target for the accelerating electrons, so that the collision produces X-rays with the best possible efficiency (in the conversion of the kinetic energy of the electrons into electromagnetic energy). The kinetic energy gained by the electrons is proportional to the potential difference that accelerates them. E.g., electrons accelerated with a potential difference of 20 and 100 kVp (kilovolt peak), gain 20 and 100 keV of energy, respectively, at the end of their path (reaching the rise).

2.1. Braking radiation

At the moment of the collision of the electrons with the rising anode, their kinetic energy is converted into other forms of energy. Most of the energy produced is heat . The remaining percentage is due to electrons that manage to reach the nucleus neighborhood of the anode material. Coulomb forces attract and slow down the electrons causing a significant loss of their kinetic energy and a change (bending) of their straight path. According to the law of conservation of energy, the kinetic energy lost by each electron (of this category) is converted into a photon X of equal energy. The X photons produced are the so-called braking radiation from the "braking" of electrons in the nucleus field (bremsstrahlung in German means braking).

How close to the nucleus the invading electron will be will also determine the amount of kinetic energy it will lose (in the electromagnetic energy of the emitted photon), since the Coulomb gravitational force increases inversely with the square of the charge distance. When the electron comes into "frontal" collision with the nucleus, the photon of maximum energy will be produced. The curve of the emission spectrum of an X-ray lamp is the distribution of the energy of the outgoing photons and essentially reflects the distribution of the distance from the nucleus (of the target material) where the conversion of energy (electron kinetics to electromagnetic) occurred.

The distribution of the number of photons per unit of energy is inevitably affected by the lamp housing and the additional filters that are inserted in the path of the X-ray beam. and its density. This percentage is significantly higher for small energy photons.

The distribution of the number of photons per unit of energy at the output of the X lamp is continuous. The minimum energy value is determined by the type and thickness of the internal filter of the lamp and is adjusted by the additional installation of external filters. Low energy photons (eg <10 keV) are undesirable in radiological examination, because they "stop" when they enter the subject (skin) and contribute only to the absorption dose and not to the formation of the image.

The main factors that affect the performance of the X-ray lamp are: (a) the atomic number of the target material (anode) and (b) the kinetic energy of the incident electrons (in the potential difference cathode-anode difference). E.g., for 100 keV electrons falling on a tungsten anode (Z = 74), a percentage <1% will be converted to X-rays (99% in heat). However, for 6 MeV electrons (typical for treatment) the percentage of X-rays produced, in terms of heat, rises to 54%.

2.2. The cathode electrode (-)

The X-ray lamp provides the environment for their production through the mechanisms of the continuous and characteristic spectrum. For diagnostic radiology, the difference between anode and cathode ranges from 20 to 150 kVp, depending on the application, while the flow rate of electrons, from the cathode to anode, ranges from 1 to 5 mA on X-ray and 100-1000 mA on standard projection x-rays, but for a very short time, in the range of 10-100 msec. These three physical quantities (potential, current, and time), adjustable on the generator control panel, determine the quality and quantity of X-rays. The cathode is the source of electrons and is in the form of a coil made of tungsten. The coil is suitably surrounded by a special metal component (which helps to form a focused narrow beam of electrons) and is leaked by a current of about 7A. The cathode produces a beam of electrons by the process of thermal emission (electrons are released from the heated cathode). In many X-ray lamps of the radio diagnostic, there are two coils, in and two cathodes of different sizes, for two different categories of diagnostic tests.

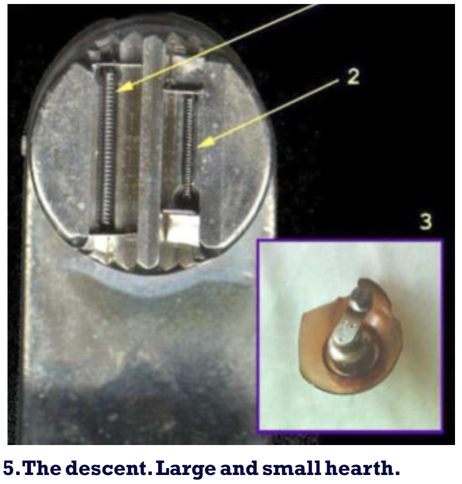


Figure 5. The descent. Large and small hearth.

2.3. The anode electrode (+)

The anode is the metal electrode that connects to the positive pole of the source and attracts the electrons repelled by the cathode towith its negative potential. The electrons that bombard the anode deposit their kinetic energy, mainly in the form of heat and less in the form of electromagnetic radiation X. To avoid the destruction of the anode by large amounts of heat, its material must be very durable, such as tungsten (W) for classical radiographs and rhodium (Rh) or molybdenum (Mo) for mammograms.

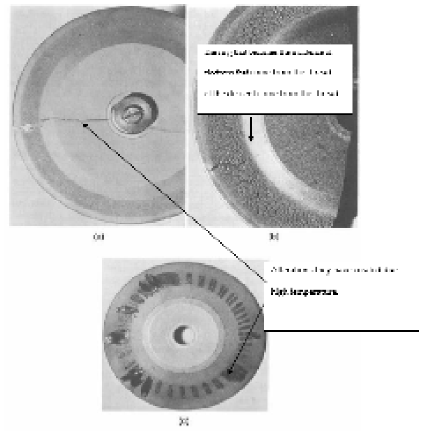


Figure 6. The anode of X-ray tube.

There are static and rotating risers. In statics, tungsten is immersed in a volume of copper, which on the one hand supports the rise, on the other hand removes the amount of heat produced as a high heat-conducting material. Small radiological devices (dental, portable) have a static rise because they are of limited strength. The rotating anode can withstand higher temperature - load. However, it has a more complex design. The rotating anode receives, at any time, at a different point on its surface the incident beam of electrons, diffusing the amount of heat to a larger surface than the static anode. The rotation speed ranges from 3000-3600 (low speeds) to 9000-10000 (high speeds) revolutions per minute. A special safety valve does not allow the ascent to be bombarded unless the ascent rotation has reached the maximum desired speed. The particularly heat-sensitive lubricant with the mechanism for rotating the anode is protected by a special construction of molybdenum which is a non-heat-conducting material. The heat radiated from the anode in the form of infrared radiation is largely removed by a special circulating oil system. The anode is essentially the source of the X-rays and for the correct display important factors are (a) the angle of the anode (the inclination of the surface of the anode with respect to the direction of the electrons - is greater than 90 ° by 7-20 °) and (b) the focal spot size, which the smaller it is, the better the spatial resolution of the x-ray (better geometry, smaller shadow).

2.4. X-ray spectrum

X-rays are electromagnetic waves with wavelengths λ= 0.1 - 100 Å

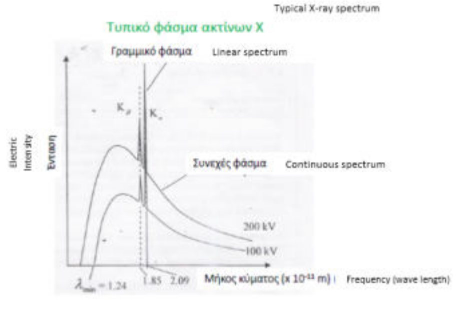


Figure 7. The graphic of X-ray spectrum.

The X-ray spectrum is complex, and consists of the linear and the continuous part:

Linear with lines of a continuous spectrum. The linear is due to the radiation emitted by the atoms of the material (eg, tungsten), into which the electrons fall. The emitted photons are the characteristic radiation of the target material. Their energies are equal to the energy difference of the layers between which the transition occurs. The energy spectrum of the characteristic radiation is therefore linear.

The continuum is due to the abrupt change (deceleration-breaking) of the velocity of the electrons upon falling on the material (of the anode). A moving electron is equivalent to an electric current, and the abrupt change in electron velocity will correspond to an abrupt change in current. This results in the production of a nonperiodic wave.

Thus, the deceleration of the electron is accompanied by a continuous emission of radiation. The limit value of the wavelength (λ) in the continuous spectrum means that there are no photons with energy greater than a limit value (λ_{op}). This limit is expressed by the relation:

$$V_{op} = h\frac{c}{\lambda_{op}} \quad (1)$$

where: í is the frequency, h the Planck constant, c the speed of light, ë the wavelength.

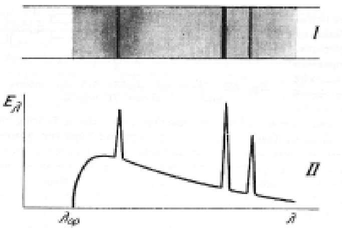


Figure 8. The X-ray spectrum.

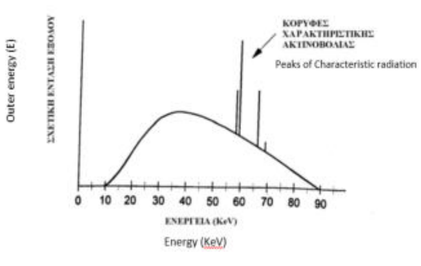


Figure 9. Full X-ray spectrum produced by a high voltage of 90 kV. In the continuous spectrum of braking radiation, the peaks of the characteristic radiation are superimposed.

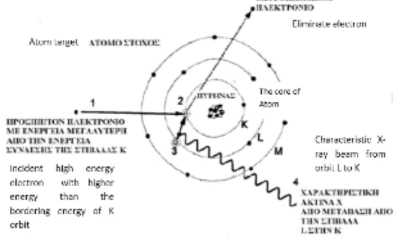


Figure 10. Production of characteristic radiation.

When an electron in the beam hits the target, it can interact with an electron inside the target atom and launch it out of the atom (ionization). The vacuum is filled by a higher layer electron and simultaneous X-ray emission. The emitted photons are the characteristic radiation of the target material. Their energies are equal to the energy difference of the layers between which the transition occurs. The energy spectrum of the characteristic radiation is therefore linear.

The shape of the spectrum depends on the number and speed of the electrons but also on the anode material. Thus, the number of photons emitted depends on the number of electrons that fall (fall) per unit time on the rise. That is, a change in the number of electrons results in a corresponding change in the intensity of the radiation and does not affect the shape of the spectrum.

A change in the velocity of the electrons causes in the linear spectrum a corresponding change in the intensity of each line in the continuous spectrum, on the one hand, a corresponding change in the intensity of the radiation, on the other hand, if the velocity of the electrons increases, the limit wavelength shifts to smaller values. We are talking about harder radiation) and larger (soft radiation) if the velocity of the electrons decreases.

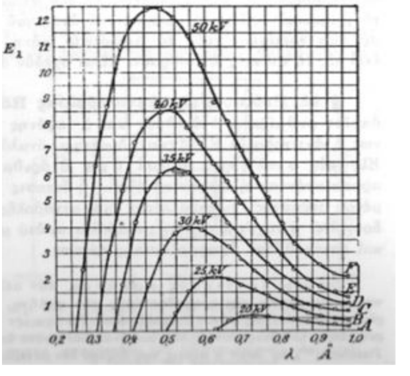


Figure 11. Continuous spectrum. Distribution of the radiation intensity for different values of the potential difference (in kV) that accelerates the electrons.

2.5. Continuous spectrum interpretation

Electromagnetic theory predicts that a decelerating (or accelerating) electric charge emits electromagnetic radiation whose spectrum is continuous. The process is called braking radiation (Bremstrahlung). The continuous spectrum of X-rays is breaking radiation that results from the abrupt deceleration of electrons within the material.

The emission rate is proportional to Z 2 q 2 / m 2 where Z is the charge of the target particles, q is the charge of the beam particles, and m is the mass of the beam particles. It therefore becomes apparent that due to the small mass of electrons, the production of X-rays is highly efficient.

The main feature of the spectrum is the marginal minimum wavelength, which is independent of the target material and depends on the acceleration potential. The reason is that the minimum wavelength corresponds to the maximum kinetic energy for which it is:

$$E_{KIN} = eV = E_{MAX} = hf_{MAX} = h\frac{c}{\lambda_{MIN}} \Rightarrow \lambda_{MIN} = \frac{hc}{eV}$$

Χρήσιμη σχέση $\lambda_{MIN} = \frac{1240}{E(eV)} nm$

2.5.1. Linear spectrum interpretation

The active beam of electrons removes electrons from the inner atomic layers (mainly 1s). This creates holes which are occupied by electron transitions from the upper layers with simultaneous X-ray emission.

3. The classical radiographic system

The lamp is glass, air-vacuum and has two poles. At the cathode of the lamp there is a filament which is the source of the electron cloud, when heated to incandescent. This is achieved by inserting a low voltage transformer, which converts the city current (220V) to 10-12V.

A high potential difference is applied to the two poles of the lamp, which is achieved with a high voltage transformer, which converts 220V to 30,000V to 150,000V (30-150 kilovolts, (kV)). The construction of a transformer is based on electromagnetic induction. With the transformer we can at least will multiply or multiply the current voltage. In the first case, the transformer is low voltage (step-down transformer) and in the second high voltage (step-up transformer). To adjust the potential difference at the poles of the lamp at will, to select the desired energy of the resulting rays, an autotransformer is inserted.

The electric current we use is alternating current (AC), which, as is well known, has two phases. In one phase one pole becomes + and the other - and in the other phase the poles are reversed and the positive becomes negative. Schematically, the alternating current is represented by a wavy line. The part of the line, which is included between two consecutive points that are in the same phase, is the wave. The full wave, that is, consists of the positive phase (the part above the baseline, which corresponds to one direction of the current) and the negative phase (the part below the baseline, when the direction of the current is reversed).

The two poles of the Rontgen lamp are connected to the poles of the high voltage transformer. If the connection is direct, it means that the poles of the lamp alternate with each change of current phase. That is, each pole of it becomes alternately positive - negative. By construction, however, the lamp has a permanently positive pole, the rise, and a permanently negative, descent. Alternating the poles would result in damage to the lamp. The avoidance of this alternation is done by rectification, i.e. elimination of the negative phase, and its conversion into a positive one. In this way, the course of the current is constantly in the same direction.

To these basic components of the radiological machine must be added the components intended for safe use. The lamp is located inside a metal cover, which completely absorbs the rays, except for the window opposite the target. The cables are special high voltage cables with special covers. The lamp is immersed in oil for thermal insulation.

In 1895 W. Roentgen discovered X-rays and their first diagnostic capabilities. Today, due to the rapid development of science and technology, radiodiagnostics and the field of medical imaging in general have an impressive development. In radiodiagnostics, the possibility of X-ray interaction with matter is utilized.

Figure 9 shows schematically the classical radiographic imaging system.

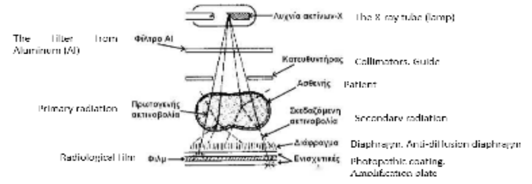


Figure 12. Classical X-ray machine.

The photons, which are emitted by the X-ray tube, enter the patient. When they interact with the patient's body, they can be scattered, absorbed, or continue their course smoothly without interacting. The primary radiation (which does not interact with the patient's body) is recorded on the film and forms the diagnostic image. However, the scattered radiation creates a signal that is "noise" and degrades the quality of the X-ray image.

To improve the image quality of the X-ray film, we use the following technological means components:

1. Filter Al. In an X-ray beam that has not been "filtered" a large number of photons have very low energies. These low-energy photons do not contribute to radiographic imaging, because most of them are absorbed by the patient's body. That is, they increase the dose (radiological burden) to the patient without transferring information to the detection system. For this reason, an aluminum filter (Al), approximately 0.5 mm thick, is placed at the output of the beam from the lamp. This removes the vast majority of photons of this low energy order.

2. Guide. The X-rays produced by the lamp are emitted in all directions. The beam of radiation, therefore, which is directed towards the output of the lamp, has a wide range and for this reason in most cases it needs configuration. The guide shapes the field both in its shape and in its size.

3. Anti-diffusion diaphragm. The X-ray beam exiting the patient and directed towards the film consists not only of primary radiation but also of scattered radiation. In contrast to the primary radiation, the scattering is created inside the patient's body during the primary's interaction with the patient. If the scattered radiation reaches the film, it will create a fog. Anti-diffusion diaphragm is the most common method of eliminating scattered radiation. It consists of thin strips of lead alternating with aluminum strips. The arrangement of the strips is such as to allow the passage of primary radiation.

4. Reinforcement plate. Fluorescent materials stimulated by X-rays are used in the amplification plate. Such materials are various minerals, such as calcium, tungsten, and the rare earths gadolinium and lanthanum. For each absorbed X photon, the amplifier emits a large number of photons in the visible part of the electromagnetic radiation spectrum. That is, the original X-ray image is mutated into visible, amplified, and captured on film. This reduces the patient's radiation exposure time.

The reinforcing plate-film system (or film only) is placed in a special cassette of suitable size. The cassette offers engineering system protection, is opaque to light, and prevents film fogging and ensures homogeneous contact between the reinforcing plate and the film.

The processing of the film and the formation of the final image, which will be used by the doctor to diagnose the patient's condition, is done in a special lighting room (dark room). However, there are also so-called "daylight processors". They pick up the film from the cassette and place a new film on it automatically.

A classical X-ray machine is shown in Figure 13 (in normal dimensions).

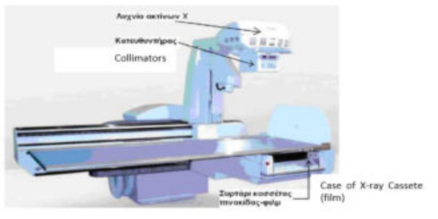


Figure 13. Classical X-ray machine.

4. Basic radiographic anatomical levels

Figure 13. Classical X-ray machine

Figure 14. The human body

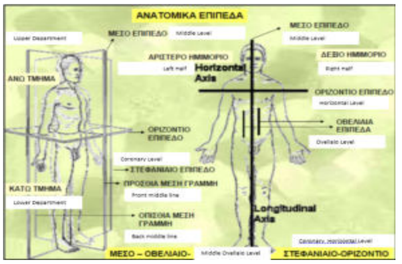


Figure 14.The anatomic levels of human body.

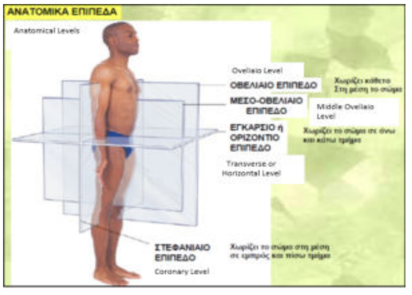


Figure 15.The anatomic levels of human body.

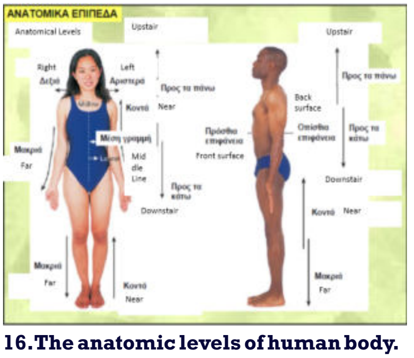


Figure 16.The anatomic levels of human body.

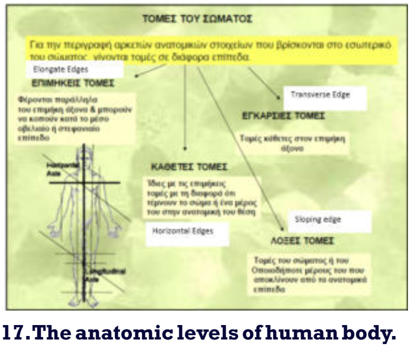


Figure 17.The anatomic levels of human body.

5.The X-ray system

Taking an x-ray image takes a very short time. Such a shot is a snapshot of the anatomical structure being examined. The received images are static and do not show the movement of the various instruments.

The motion can only be attributed to the increase in the duration of radiation exposure. These types of shots are called x-rays. X-ray is a form of continuous imaging. Used to realize potential operational studies.

In addition to the performance of the movement, the X-ray is also used for the visual identification of anatomical structures that are of diagnostic interest, to obtain better X-rays. The X-ray systems used have an X-ray tube similar to that used for X-rays. The images are presented either with the so-called fluorescent screens, or with the use of video amplifiers connected to a closed-circuit television. In Figure 18 shows the basic structure of an X-ray system which uses image intensifier.

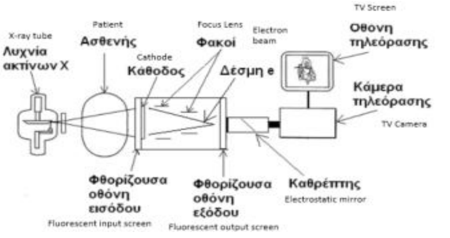


Figure 18.X-ray system with image amplifier.

As we observe, the X-ray beam coming out of the patient's body hits the fluorescent input screen. There a part of it is converted into visible light (fluorescent effect). Visible light photons reach the photocathode. The photocathode is made of semiconductor material eg, Cs, 3, Sb. These materials emit electrons when they absorb a quantity of energy. The number of electrons emitted is proportional to the number of visible photons. For 1000 photons, about 100 electrons are emitted. Because a high potential difference is applied between the photocathode and the anode, the electrons accelerate in the direction of the anode. On their way up, the electrons are focused by the electrostatic lenses. That is, the beam of electrons acquires a conical shape (in Figure 18 it appears triangular). The electrons then hit the fluorescent output screen. The role of this screen is to convert the energy of electrons into visible photons. The distribution of these photons on the surface of the output screen is the final radiographic image.

Outside the glass tube of the amplifier, there is a suitable system for observing the X-ray image of optical coupling with the fluorescent output screen. Through this system, the image can be recorded by a film camera or projected through a closed-circuit television.

Image amplifiers are devices that have replaced fluorescent screens in modern X-ray systems. These amplifiers serve the need for satisfactory brightness of the formed image without increasing the intensity of the X-rays. In some cases, the connection arm to the lamp is semicircular, C-shaped, e.g. angiographic machines. In Figure 19 is shown an x-ray C-arm system.

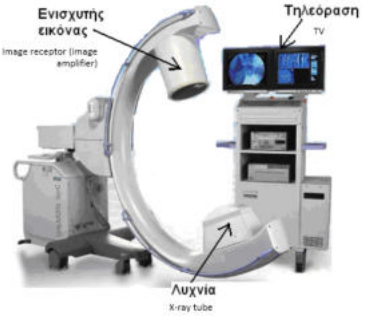


Figure 19. C-arm X-ray machine.

Clinical applications of X-ray - X-ray:

Plain radiographs, and especially chest x-rays, are radiological examinations performed by all physicians, regardless of specialty. It is known that the cardiologist, the pulmonologist, and the thoracic surgeon do not make a final diagnosis if there is no strengthening of the chest x-ray.

The main pathological findings that can be seen on plain X-rays are:

The calcifications of soft molecules (muscles, ligaments, etc.).
Bone fractures.
The pulmonary hematoma.
cervical syndrome.

- Spinal deformities (eg, scoliosis)
- Abnormalities in the shape and position of the organs of the urinary system (kidneys, liver, etc.).

Moreover the study of the digestive system can be done very well with the use of the classical radiographic - X-ray system. For the imaging of the gastrointestinal tract, we use the X-ray examination, in order to study the physiology of the various molecules but also to select the appropriate places for taking x-rays. These x-rays may cover the entire organ being examined - esophagus, stomach, and large intestine - or be local to part of it.

6. The digital radiodiagnostic

Classical radiology systems record and display data in analog form. For example, X-ray film has a surface on which thousands of shades of gray have been recorded, if there is a continuous information without gradation. This image is not editable and is obtained under strict irradiation conditions. Otherwise, the image obtained will not be useful diagnostically and the test will have to be repeated. Digital X-ray systems, on the other hand, offer the ability to generate useful image diagnostics at any desired level of radiation. This image can be utilized in a variety of ways (screen display, film printing, optical disc storage). Digital systems are more economically expensive than conventional ones, but in an age of rapid technological development they find a large scope in hospital applications.

6.1. The structure of the digital radiographic system

The Figure 19 shows the individual parts of a typical digital radiographic system. The X-ray lamp and the radiation detector are functionally connected to a computer. The resulting image is stored and digitally processed. It is then displayed on a TV screen, which is part of the machine operator's control console. Axial and magnetic resonance imaging systems have similar consoles. As observed in Figure 20 , the computer controls the operation phases of the individual parts of the imaging system and plays a key role in the formation of the final image. That is, the essential difference from conventional radiology is in the use of this electronic system.

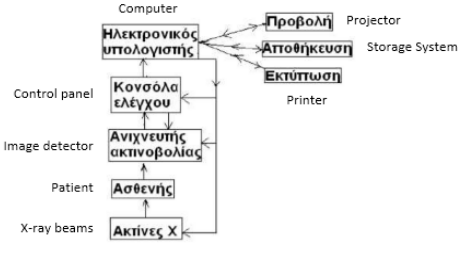


Figure 20. The structure of the digital radiographic system.

A digital image is basically a square array of numbers. This device is also called a digital matrix. Each numerical value corresponds to the size of a certain physical parameter, e.g., radiation attenuation factor, radiopharmaceutical concentration, etc. In computed tomography the attenuation factor is used and in nuclear medicine the radiopharmaceutical concentration is used. Essentially, the digital matrix expresses the variation (change) of the physical parameters on a flat surface. The calculation of numerical values and their distribution in the digital matrix is done by the computer. This calculation is performed based on the radiation measurements from the detector of the imaging system. The transition from the digital matrix to a visible diagnostic image is achieved through a process of matching shades of one or more colors to numerical values. E.g., if a range of shades of gray is selected, then the small values correspond to "weak" shades which gradually become more intense as the prices increases. Many different colors are often used instead of shades of one color. In this way, a certain shade is placed in the place of each number. An arrangement of "colored" squares is thus formed (figure 21). These squares are defined as image elements or pixels.

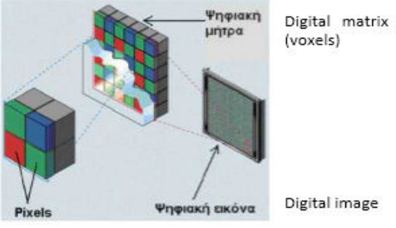


Figure 21. Digital matrix and pixels.

6.2. The advantages of digital radiodiagnostics

The advantages of digital X-ray systems can be classified into four categories: a) image projection, b) dose reduction, c) image processing, and d) image storage and retrieval. Regarding the first category, we point out that the brightness of the TV screen or the optical density of a film can be fully utilized in the area of interest. This means that in the image we receive, we take full advantage of the technical characteristics of the television (pixel number, brightness scale) or the film (optical density range) in the area that needs the most attention to ("window" technique). Therefore, an improvement in resolution and contrast is achieved.

Dose reduction is also an important advantage of digital radiography. In conventional radiology, the radial load is determined by the sensitivity of the image detector (fluorescent screen or optical film density range). In digital radiology, dose reduction is achieved, since any reduction in contrast, due to reduced radiation, is compensated through the "window" technique mentioned earlier.

Image processing is undoubtedly another point of excellence in digital radiology. Perhaps the most important application of image processing is abstract imaging. A typical example is abstract angiography, which uses the so-called "mask subtraction technique".

During this process, the X-ray tube emits pulsed radiation. In this way, successive shots of the area of diagnostic interest are taken and these images are used as a "mask". Iodine contrast agent is then injected into the patient (intravenously or intraarterially) and new images are taken. Each individual download is digitized and stored in the digital processing unit memory (inside the computer). An image that does not contain a descriptor is then removed from an image that contains a descriptor inside this unit. The end result is the emergence in a final image of only the structures (vessels) that contain contrast (figure 22).

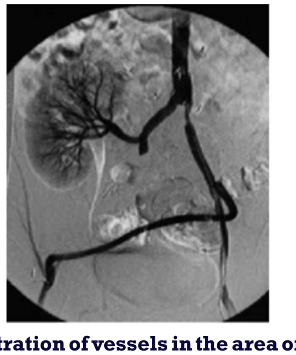


Figure 22. Illustration of vessels in the area of the kidney.

Finally, the storage of the image on an optical disc or on a magnetic medium contains a very high degree of security by maintaining the image at an excellent quality level. In addition, image archiving and space saving is a essential parameter to consider. The dozens of X-ray films produced every day do not leave much room for proper storage (in suitable environmental conditions), nor for easy finding of the X-ray image we want in a short time. It therefore becomes obvious why the digitization of the image facilitates the working conditions of the hospital staff.

7.The CT scan

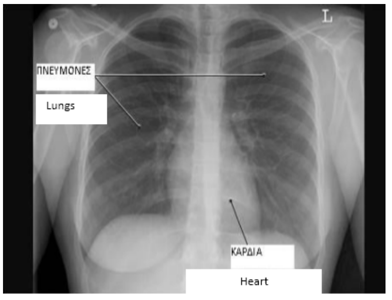


Figure 23. Chest x-ray.

When we observe a chest x-ray (figure 23), specific anatomical structures become immediately apparent. The chest walls, for example, are depicted as light arcs because they absorb more of the X-ray beam than the surrounding soft tissue, and therefore the film is exposed to less radiation behind the bone area. Correspondingly, lungs that are air-filled cavities are depicted as dark areas. The difference in the degree of contrast between two anatomical structures allows or not to be observed by the human eye. Table 1 shows the % difference in the degree of contrast between certain tissue tissues and muscle tissue.

Table 1. Degree of contrast of certain biological tissues.

Material element	Difference (%) in relation to muscle tissue
Air	+20
Blood	+0.2
Muscle	0
Bone	-26

X-ray films allow a relative contrast of 2% to be easily discernible, so a 1cm thick bone or a 1cm diameter air cavity is clearly imprinted on the film. However, the blood inside the vessels (arteries and veins) and other soft tissues, such as the heart, cannot be satisfactorily imaged with a standard x-ray.

Another problem with conventional radiography is the loss of depth-related information. The problem arises because the three-dimensional structure of the body is projected on two-dimensional X-ray film.

Clearly, therefore, classical radiographic images are unsuitable both for imaging between different types of soft tissue and for spatial analysis of anatomical structures in the direction of radiation transmission.

7.1. General description of the CT scanner

In Figure 23 shows the general layout of computed tomography. The CT shell is the most bulky and visible element. The X-ray lamp and the detectors rotate inside the shell. In the middle there is a large hole, through which the body of the examinee passes. The shell can be rotated around the axis passing through its supports, so that it is possible to take inclined in addition to vertical sections.

The test bench (electric bed) moves in such a direction that each time another part of the examinee's body comes into the hole of the shell. With this movement, successive sections are obtained. Since each incision covers about 1 cm on the body, the bed should be moved 10 times to cover 10 cm along the body of the examinee. Another component of IT is the control and control console. Usually inside the console is the computer, that is, the brain of the system. Specifically, it commands the system to receive the sections according to the data (KV, mAs, section thickness), collects the digital signals and stores them in its memory, and then processes them with mathematical equations, creating a table of numbers corresponding to the section image..

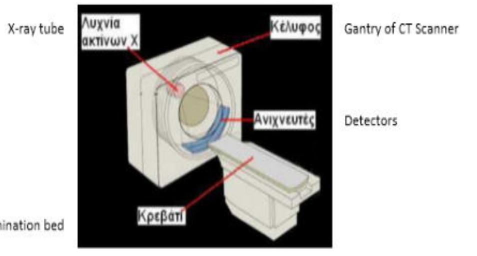


Figure 23. General CT scanner.

7.1.1. X-ray output lamp

The first X-ray tubes placed on the HVs had a steady rise and a large focus. Moreover in the first experimental systems CT were used radioactive isotopes that provided a monoenergetic beam. The single-energy beam contributes to the most accurate and simplest reconstruction of the image. However, the intensity of the isotope radiation was too low to be useful in creating an image suitable for medical diagnosis.

Modern CT systems use an X-ray lamp, in which electrons are generated and accelerated which then fall to the anode of the lamp emitting X-rays. The lamp has a rotating anode and a very small focus. The typical operating voltage of the lamp is 100 to 120kV, and it does not change significantly during the different types of tests.

The value of the anode current of the lamp, measured in mA, when multiplied by the operating time of the lamp, measured in sec, gives a characteristic physical quantity called mAs. The value of mAs varies from test to test. For example, 230 mAs are usually used in the head and 115 mAs in the body.

7.1.2. The operation of the CT scanner (YT)

The principle of operation of a PC system is understood with the help of Figure 23. A thin triangular beam radiates the patient from various angles so that an imaginary slice of his body is irradiated. The radiation that passes through the patient is counted by the detectors.

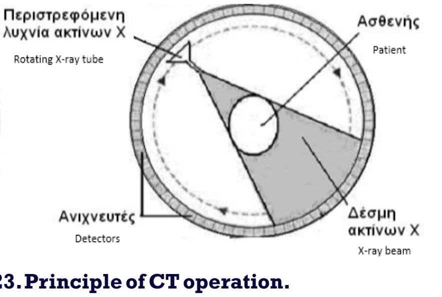


Figure 23. Principle of CT operation.

Each detector produces an electrical signal whose intensity is proportional to the intensity of the radiation it counts. This signal is transmitted to the computer. The computer first divides the irradiated slice into elementary pieces (cubes). Then, based on: a) the values of the intensity of the initial radiation and b) the value of the electrical signals received by the detector, assigned to each elementary cube a shade of gray. Eventually, the incision made through this whole process on the computer screen renders quite clearly the inner plane of the body in that position. An example of a CT scan of the lower abdomen is shown in Figure 24.

Modern computed tomography systems have the ability to take sections at various levels (Figure 25) . Specifically, the incisions obtained can be transverse, coronary, and sagittal.

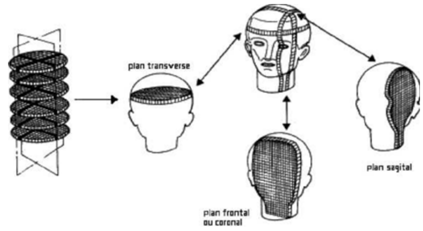


Figure 25. Transverse, coronal and sagittal.

The clinical applications of computed tomography
The most common clinical cases in which computed tomography is used are diagnosis:

- Injuries to the spine and head.
- Intracranial tumors.
- Cerebral hematomas
- Ocular injuries.
- Gastrointestinal lesions.
- Hepatic metastases.

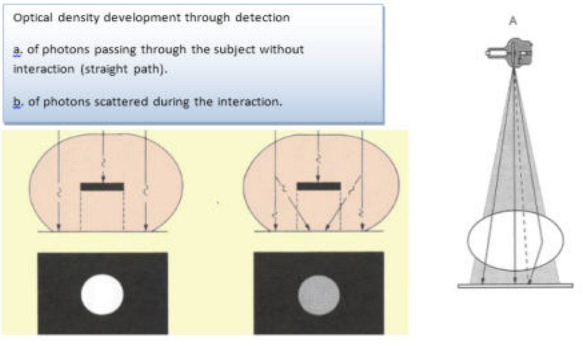
Computed tomography is also used:

- For the imaging of the chest walls.
- For the evaluation of intestinal obstructio
- For the examination of large vessels.

8. Basic parameters of radiological image

The ideal image of optical density (OP), includes areas of increased optical density (clarifications) corresponding to areas of the anatomical subject that allow many photons to pass without interaction and areas of reduced optical density (shading) corresponding to areas of the anatomical subject that absorbed a lot of photons.

The scattering of photons (Compton effect) leads to the development of optical density at points that depend on their scattering angle, resulting in a reduction of the contrast contrast, in the difference in the optical density of neighboring areas.



Ideal image Increased contrast contrast. Corresponds to zero percentage of scattered radiation.

Real picture. Reduced contrast contrast. Corresponds to a non-zero percentage of scattered radiation.

Figure 26. Radiological images.

Therefore for a suitable optical density

Scattered radiation leads to a decrease in contrast contrast

The percentage of scattered radiation that will be produced in each irradiation depends on:

a. the kVp value
b. the thickness of the subject
c. the amplitude of the useful beam, i.e., the size of the radiation field kVp

The kVp value selected determines the penetration of the beam and the probability of a Compton effect.

An increase in kVp leads to an increase in the energy of the photons and consequently to an increase in the probability of a Compton effect (~ 1 / E) compared to the probability of a photoelectric effect (~ 1 / E 3). This is more intense for energies above 60 kVp.

An increase in kVp leads to an increase in scattered

Thread thickness

The thickness of the subject determines the number of interactions of photons with matter and consequently the probability of a Compton effect.

An increase in thickness leads to an increase in the number of interactions of photons with matter and thus an increase in the Compton effect.

an increase in subject thickness leads to an increase in scattered radiation

Beam amplitude - size of radiation field

The amplitude of the beam, in the size of the field of radiation, determines the number of interactions of photons with matter through the amplitude of the matter it covers and through the number of photons that interact with this amplitude.

An increase in beam amplitude leads to an increase in the number of interactions and thus an increase in the Compton effect.

increase in beam amplitude - field size of radiation leads to increase in scattered radiation

scattered radiation by influencing the factors that determine it as well as the negatives of this change.

Factor	Change	effect of change	
		As for the SA	Parallel effect
KVp	Reduction	reduction of scattered radiation, therefore, improving contrast contrast	1. reducing the number of beam photons 2. photoelectric increase (dose) therefore, 3. increase mAs for OP maintenance
field size	Reduction	reduction of scattered radiation therefore improving contrast contrast	reduction in the number of photons therefore increase mAs for OP maintenance
thickness of the subject	reduction (compression)	reduction of scattered radiation therefore improving contrast contrast	

The reduction of the beam width is achieved through the use of apertures that are placed in the output window of the lamp and which are made of metal or metal alloys that significantly absorb X-rays.

The apertures can be flat - hole, cones, cylinders which give a field size proportional to their construction, they can not be adjusted and negatively affect the clarity of the image, mainly at the borders, due to geometric factors. Comparatively, the rollers contribute to less ambiguity compared to the holes, which is why they are used in specific tests.

The most convenient baffles are the depth baffles which consist of 2 pairs of movable sheet- lead bars , independent of movement per pair, contained in the baffle box. They have an advantage over the rest in the possibility of producing a field of different sizes, depending on the needs.

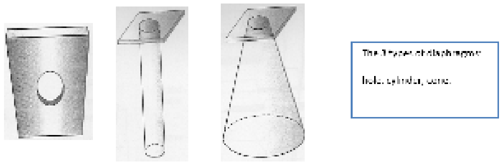


Figure 27. The types of diagrams.

In addition, it is possible to reduce the percentage of scattered radiation detected by the imaging system with

1. the use of anti-scattering diaphragm (AD)
is a device that reduces the amount of scattered radiation detected by the imaging system and not the scattered radiation produced

2. with the projector vacuum technique

- ✓ To limit the scattered radiation and radiation protection are required:
- ✓ use kVp depending on the topic,
- ✓ field limitation at the boundaries of the anatomical area of interest
- ✓ use of a fun diaphragm when necessary

In digital imaging, where the imaging system responds to a wider range of energies of X photons, mainly low energy such as scattering, more attention is required to limit the field of radiation and to use AD. With appropriate adjustment of exposure data

8.1. The Bucky

It is a flat device, discovered in 1913 by G. Bucky, and is the most effective way to reduce the scattered radiation detected by the imaging system.

It is placed between the subject and the imaging system to cut off the scattered radiation produced during the primary beam-anatomical subject interaction, helping to improve the contrast contrast of the produced image.

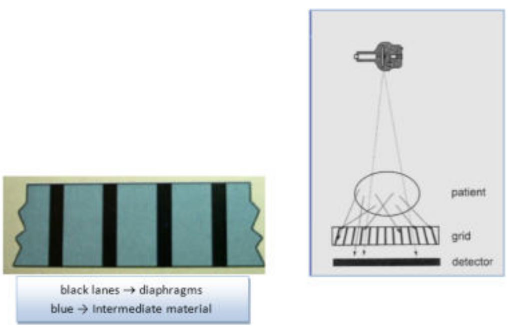
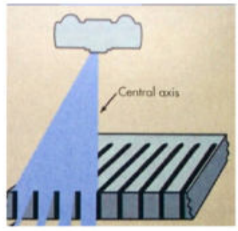


Figure 28. The block diagram of grid (Bucky).

The device is a thin rectangular sheet large enough to cover each cassette. It is surrounded by aluminum sheets, which provide stability and protection from moisture. Internally, it contains lead plates (baffles) of specific thickness and height, which are kept at equal distances from each other through the insertion of a radically permeable material, in material with a small specific absorption coefficient of radiation (aluminum, plastic) Ideally, the antiscattering diaphragm (AD) should absorb all scattering and allow the photons that pass through the subject without interaction to pass unaffected.

In reality, however, AD absorbs all photons that fall on the aperture, that is, a) from the scattered ones that have a suitable scattering angle to reach the aperture a and b) from the passing photons useful for the image that due to the diverging beam fall on these (cut) .



Due to the divergent path of "useful" photons, the farther I go from the central beam of the beam, the more photons fall on the diaphragms, causing them to be absorbed. The phenomenon is more intense in the parallel AD.

Figure 29. The central axis of x-ray beam from the source to grid.

USE AD	
Advantage	significant reduction in scattered radiation reaching the detector increase in contrast contrast.
Disadvantage	absorption of photons from AD increase mAs (number of photons) to maintain OP decrease radiation protection.

8.1.1. Features A.D.

The characteristics of an A.D. are structural, depending on the thickness of the diaphragm, the thickness of the intermediate material, and the height of the diaphragm, in the height of the AD. and are written on the side that should be facing the lamp. Specifically:

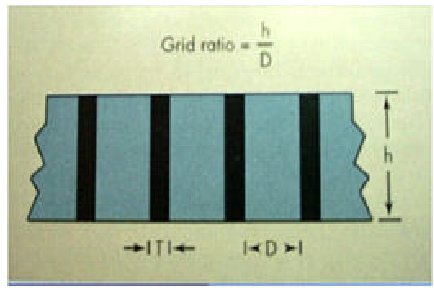


Figure 30. The Grid of ratio h/D.

1. Reason A.D. (r) is the quotient of the height (h) of the diaphragm to the thickness (D) of the gap, is the distance between two consecutive diaphragms

Increase r →
↑ Absorbance of scatter photons → ↑ constricting contrast
and ↑ absorbance «useful» photons
So,
↓ photons which arrived to detector drive to ↑mAs for the conservation of the Optical Den city

with values 5:1, 6:1, 8:1, 12:1, 16:1

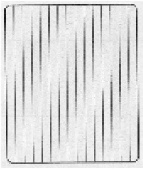
2. Density (frequency) AD is called the number of apertures per unit length (cm) and ranges from 25 to 40 apertures / cm

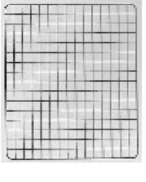
Increse of den city → decrece the gap (D) → **incense r** →
↑ Absorbance of scatter photons → ↑ contrasting contrast
And ↑ absorbance «useful» photons
So
↓ Photons which arrived to detector drive to ↑ mAs for the conservation of the Optical Den city

The following table lists the items A.D.

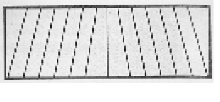
ITEMS AD			
Categories	Advantages	disadvantages	
by reason	high speech (12: 1, 16: 1)	increase in contrast contrast	radiation protection reduction
	low speech (5: 1, 6: 1, 8: 1)	slight increase in contrast contrast	less reduction in radiation protection

based on a diaphragm arrangement	Linearly	possibility of tilting a lamp along apertures	increased septal incision at the boundaries of the beam
	intersecting	greater reduction of scattered radiation, due to the arrangement of baffles in two directions	do not allow inclination of the lamp
based on diaphragm orientation	alongside (not focused)	possibility of tilting a lamp along apertures	increased septal cleavage at the beam boundaries
	Focused (tilt of apertures towards lamp focus)	reduction of diaphragmaticc ut due to inclination and direction in parallel in the divergent primary beam	1. restriction in E.A. (must be contained in the range EA imposed by the convergence of the diaphragms and written on the AD)
			2. do not allow inclination of the lamp and the central beam to always pass through the center of the AD.
based on movement	Properties (used on portable) are placed on or contained on the cassette	increase in contrast contrast	Diaphragm illustration
	animated (contained in the cassette drawer)	1.increase contrast contrast 2. Blurring illustration of apertures	effect (small) geometrically on the image due to projection distance
			increased exposure data in relation to real estate due to cut-off





Parallel Antiscatter Grid from the side.



Linear A.D. from above

Crossed AD from above (resulting from the combination of 2 linear ADs oriented lengthwise and widthwise) respectively).

Focused AD from the side.

8.1.2.Yield AD

The A.D. was used to improve the contrast contrast through the absorption of scattered photons. The higher the ratio of A.D. or its density, the greater the reduction of scattered radiation and consequently the improvement of the contrast contrast. In parallel with the absorption of scattered photons, AD. absorbs photons that pass through the subject without interacting with it.

The above effects lead to an overall reduction in the number of photons incident on the imaging system and therefore an increase in the amount of useful beam (number of photons) required to reach the patient is required to maintain the optical density, in an increase in mAs.

The change in mAs is determined by the Bucky factor (BF) or correction factor (SD), which expresses how much the mAs should be increased (ie, the radiation protection will be reduced) during the use of AD, in relation to the corresponding ones without AD, to achieve the same optical density

$$BF = \frac{mAs_{with\ AD}}{mAs_{without\ AD}} \qquad (3)$$

Bucky factor (BF) or correction factor (SD) depends on the ratio of AD. The higher the ratio of AD, the greater the S.D. as shown in the table:

Reason A.D. (r)	Coefficient q correction (SI)
without ID	1
5: 1	2
6: 1	3
8: 1	4
12: 1	5
16: 1	6

The correction of the mAs required to achieve the same OP in two radiological images made using AD. Different ratio is calculated through the relation:

$$\frac{\Sigma.\delta_{new\ A.D}}{\Sigma.\delta_{start\ A.D.}} = \frac{mAs_{new A.D}}{mAs_{start\ A.D}} \qquad (4)$$

8.1.3. Disadvantages - mistakes of using AD

The main disadvantage of using AD is the increase of the dose in the examined compared to the corresponding radiography without A.D. and the higher ratio of A.D.

An additional disadvantage for the focused ones is the possible aperture cut-off, is the reduction of the number of passing "useful" photons that fall in the image recording system (and therefore the reduction of the OP) due to an error during the use of the AD.

Types of erros

1. Inverted placement of a focused AD. In this error, the direction of the septa of the AD. is opposite to the divergent direction of the beam, resulting in significant photon excitation as we move away from the center beam of the beam, reducing the optical density (exposure).

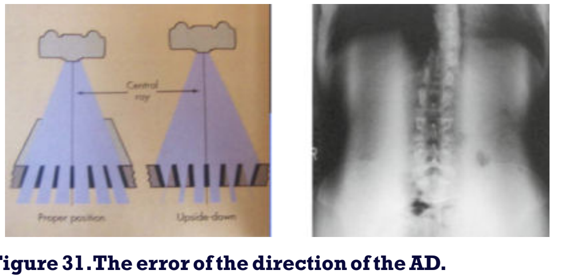


Figure 31.The error of the direction of the AD.

The error is avoided by having an indication on the AD. which now indicates the side is placed towards the lamp.

2. Placement of A.D. at an angle is observed in parallel and focused AD. when there is a slope of the lamp or a slope of the AD. and leads to an overall reduction in optical density.

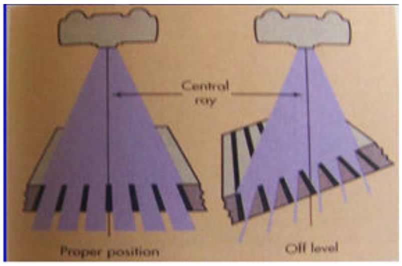


Figure 31. The error of the angle A.D.

The error is avoided by concentrating the central radius so that it is brought perpendicular to the AD.

3. Positioning of focused AD eccentrics is observed when the central radius of the beam does not pass through the center of the AD, so the direction of the photons of the beam due to the divergent direction does not coincide with the direction of inclination of the septa resulting in their absorption and overall reduction of OP (optical density) .

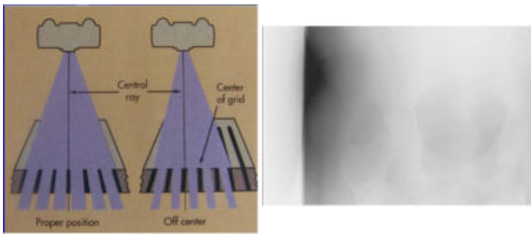


Figure 32. The Positioning of focused AD eccentrics.

The error is avoided by properly concentrating the central radius so that it passes through the center of the AD. and perpendicular to it.

4. Use of EA outside the permissible values of focused AD. is observed when using E.A., which deviates significantly from the focus range of a focused AD. Due to the divergent direction, the direction of the beams of the beam towards the limit does not coincide with the direction of inclination of the aperture, leading to a reduction of OP in the periphery of the image.

In the focused AD. The extensions of the diaphragms converge at a point, a point of focus, which determines the focal length of the AD. (indicated), in E.A. (focal length) to be used so that the beams of the beam are parallel to the diaphragms. The higher the ratio of A.D. limited is the EA (focal length) range that can be used.

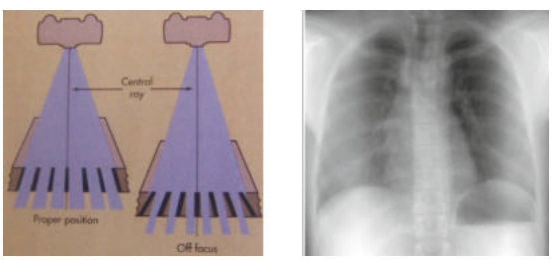


Figure 33. The use of EA outside the permissible values of focused AD.

The error is avoided by using a suitable E.A. (due to restrictions on laptops, focused ADs are not used).

8.1.4. Conclusions

The use or not of A.D. is determined by the value of kVp to be used. The higher the value of kVp, the higher the ratio of A.D., which is required for satisfactory SA (contrast contrast).

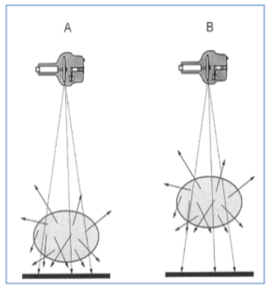
AD use for very low kVp is done only for very high contrast contrast requirements, e.g., mammography, whenever AD is used. short speech

The choice of A.D. should be done with criteria for the improvement of the contrast, the dose of the examinee, and the possibility of diaphragmatic excision

Use A.D. when kVp ≥ 55 - 60 And thickness πάχος subject ≥ 10cm	The higher of radio of A.D. ✓ the greater the increase in contrast, ✓ the higher the dose of the subject and ✓ or the greater the chance of a diaphragmatic incision

8.2. Projector removal technique (Projector gap)

The air gap technique is an alternative method of limiting the scattered radiation detected by the imaging system, by removing the imaging subject from the imaging system, is increasing the projection distance (PA).



Scattered photons are emitted at different angles, depending on the initial energy of the photons in the beam. Increasing the projection distance increases the probability that some of them will not fall into the imaging system, leading to an increase in the contrast.

The scattering angle depends on the energy of the photons. The higher the kVp the smaller the scattering angle so the benefit is small. Therefore the method is only used for low kVp.

Figure 34: The projector gap.

The longer the projection distance, the less scattered radiation is detected by the recording system and consequently the more the contrast improves. If the number of photons incident in the imaging system is sufficient to develop a satisfactory optical density, then it is a method that contributes positively to the improvement of the contrast without increasing the dose to the subject.

In general, however, the increase of PA leads to beam readjustment, and thus an increase in mAs, at a rate equal to or slightly less than that corresponding to the use of AD (eg for an increase in PA of 10-15 cm D. speech 8:1)

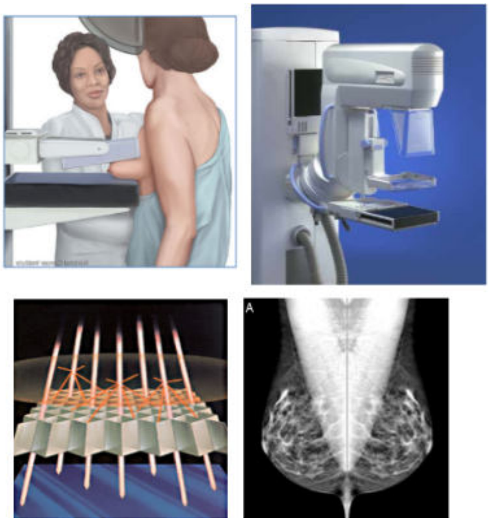
The main disadvantage of the method is the effect of increasing the PA. (projection distance) in the distortion - magnification of the image, which is treated by increasing the focal length, whenever possible.

Figure 35: In the left X-ray, the A.D is closer to the patient, so we increase the contrast of image. In the right X-ray, the longer projection distance (PA), the less scattered radiation is detected by the recording system and consequently the more contrast improves better than the left X-ray image.

8.3. Mammography

This is the technique with the highest requirements in terms of image quality. The mammogram uses a special radiological machine. The main features of the technique are:

1. Radiation lamps with anodes from molybdenum or other metal alloys that have a high photon efficiency around 25-30 kVp.
2. Application of the heel effect in the orientation of the lamp.
3. Breast pressure.
4. Use of antiscattering diaphragm.
5. Cassette with an OP (reinforcing plate).
6. Single coated radiological film.



9. Radiological image quality

An X-ray image is satisfactory when it highlights (makes visible) the details of the anatomy that are important in assessing an anatomical area. An x-ray can be ideal, if it highlights the anatomical elements in an ideal way. It may be diagnostic, that is, it highlights the anatomical features to the extent that it allows safe diagnosis, but not ideally. It may not be acceptable when it does not highlight the anatomical features to the extent that it allows a safe diagnosis, at which point it must be repeated. Satisfactory highlighting of anatomical elements requires a balanced relationship between radiological density and contrast.

9.1. Radiographic density (density)

Radiological density expresses the degree of darkening that a radiographic image exhibits overall. Darkening means how black color looks to the human eye in an area of the image. In order for the human eye to see the information in a radiological image, it must be displayed with specific densities that are gradations of the scale of shades of gray with extreme colors white and black.

X-rays, after interacting with the object / anatomical subject and after undergoing quantitative and qualitative changes, fall into the recording system where new interactions occur that lead to the development of darkening. The darkening that develops, and consequently the shade of gray caused in the final image, is proportional to the energy of the photon leaving the patient, which interacts with the detector, is:

- Increased energy photons increased density → "black"
- Reduced photons low density → "white"

The human eye and to a large extent the recording system can not estimate the density information caused by the effect of a single photon, but by the total effect of photons falling on an area. Therefore it also applies to:

Large number of photons increased density → "black"
Low number of photons low density → "white"

From the above we understand that the density that a radiological image will display depends on the intensity of the beam (number and energy of the photons) that will reach the detector. In addition to the development of density are influenced by the structural characteristics of the detector and the possibilities of processing the information (recorded by him).

The goal of the TA (radiologist, technologist) is to reach the detector with the required dose (intensity) of radiation that will cause the desired density in the image. The detector does not record information about focal length, kV, mAs, and somatometric data of the patient, but only the intensity of radiation that must be compared to develop the corresponding density in the image.

The estimation of the optical density of an x-ray is a result of the general sense that is created regarding the adequate highlighting of the anatomical structures. With knowledge and experience, the TA can judge the adequacy of density in an x-ray.

An X-ray with high overall density (overexposed) or one with overall low density (overexposed) does not usually satisfactorily highlight the details needed for diagnosis, see the following chest X-rays.

Figure 37. The second image of the skull shows increased visual density (overexposed) compared to the first (underexposed) but is diagnostic to highlight the specific problem (presence of foreign bodies).

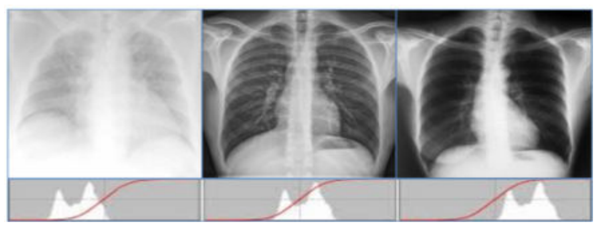


Figure 38: The first x-ray image is underexposed because the sigmoid characteristic is out out of the operation window of the film. The second x-ray image is inside the sigmoid characteristic of the operation window film, and it is better than the first and third. And the third x-ray image is overexposed.

If the image is captured on a film (transparency) for diagnosis, it is placed in a transparency, a device that provides a specific intensity, homogeneous light that penetrates the film and falls on the eye of the observer.

For transparent translucent bodies, "black" is the color that cuts almost all wavelengths, is all light emitted by the transparency, while "white" is the color that allows the passage of all wavelengths, is all light.

Figure 39. X-ray on a transposcope.

high amount of light passes through and reaches the eye of the observer → "white" areas,

a small amount of light passes through and reaches the eye of the observer → "black" areas

Optical density is expressed mathematically as a comparison of the intensity of the visible light incident on the film through the transfoscope and the intensity of the visible light passing through it at each point in the image.

For the human eye, the optical density obeys the relationship:

$$\text{Optical density} = \log 10 \frac{I_{in}}{I_{out}} \qquad (5)$$

The exact value of the optical density per point is accurately determined by means of special instruments called optical densitometers.

The above applies when we refer to the density of the radiological image and this is the way we see the subject in classical radiology.
Later we will see that in computed tomography (CT) imaging we use the term density referring not to the image but to the anatomical structures, so high density is considered a structure that absorbs the radiographic beam (□ white in the image) and low density are the structures that do not absorb the radiation (□ black in the picture).

9.1.1. Parameters that affect the density of an x-ray

The amount of photons (mAs) that fall on the detector is the pre-eminent parameter that affects the radiographic density and the one that is mainly used for its regulation.

We have already described how the product mAs regulates the number of photons in a direct ratio. Provided that the photons have sufficient penetration to penetrate the anatomical subject, increasing the mAs increases the image density and decreasing the mAs decreases the image density. The change can be either mA or sec or both, but the final effect on the image will depend on their product.

Increasing either mA or time, or both increases mAs, decreasing mA or time, or both decreases mAs. For a constant number of photons, if one parameter increases, the other decreases so that their output remains constant.

Example 40 mAs = 20 mA x 2 sec or 10 mA x 4 sec or 100 mA x 0.25 sec or

> ***mAs:*** determine the number of photons in the useful beam and therefore the number of photons that pass through the subject and interact with the detector

If an x-ray needs to be repeated due to low density, then the new mAs should be at least 2 times. In the case of overexposed radiographs, the new mAs should be at least half. If even greater change is needed, then 4-fold or 4-fold mAs should be selected compared to the initials.

We have already discussed how the quality of the radiation beam (kVp) affects the number of photons in the radiation beam. Therefore, they also affect the density of the radiological image. The increase in kVp increases and the decrease in kVp decreases the density of the x-ray. The effect of kVp on the amount of photons reaching the detector in practice is twofold: a. the increase of kV increases the amount of photons a and b. the increase in kV increases the penetration of the photons and therefore the number of photons that will reach the detector. The reduction of kV has the opposite effect. KVs affect the density of the radiographic image, but their effect is not uniform over the whole range of kV values. In addition, kV affects other quality characteristics of the radiological image. For this reason, they are not used as the first choice for adjusting the density of the x-ray. However, sometimes they must inevitably be used as portable machines where mAs price options are relatively limited.

> ***KV: determine a. the penetration of photons and hence the number of photons that reach the detector and b. increase the number of photons in the useful beam→ KV increase leads to an increase in optical density***

When we use kV to adjust the density, then the law of 15% applies, which states that: increasing the value of kV by 15% has the same effect on the image density that has 2 times the mAs. Moreover the reduction of the kV value by 15% has the same effect on the image density as the doubling of the mAs. With the same reasoning, if we increase the value of kV by 15% and use half mAs, the image density will remain constant. To calculate + 15%, we multiply the initial value kV x 1.15. To calculate -15%, we multiply the initial value kV x 0.85.

The focal length (distance of the anode focus from the detector) affects the optical density because it changes the intensity of the photons in the field of radiation based on the law of inverse of the square of the distance (see input notes.

> ***Focal length: affects the intensity of the useful beam reaching the anatomical subject - field of radiation and consequently the intensity of the outgoing radiation to the detector→ increasing the focal length leads to a decrease in radiological density and ↓ of focal length leads to an increase in radiological density***

The formula that connects the intensity of the radiation in the field of radiation with the focal length (law of inverse of the square of the distance) is:

$$\frac{I1}{I2} = \left(\frac{d2}{d1}\right)^2 \qquad (6)$$

This formula measures the intensity of radiation depending on the distance from the source for kV and mAs data. In clinical practice, we use it mainly to answer the question: How does the distance affect the radiation dose received by the TA (radiologist) and the environment? (radiation protection application)

When an X-ray is taken, it is true that to produce the required radiological density in the image, a certain photon intensity must reach the detector, regardless of the distance . So the question is: How should the TA (radiologist) modify the mAs in the event of a change in distance so that the intensity of the photons received by the detector remains constant? (application of radiological exposure).

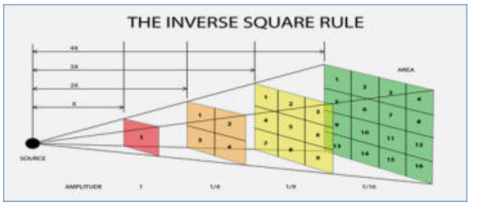


Figure 40. The law of 15%.

If we pay attention to the shape that explains the law of inversion of the square of the distance, what the TA (radiologist) has to do is adjust the exposure so that, regardless of the focal length (x, 2x, 3x, 4x) it passes from each of the colored squares the same number of photons passing through a pink square. That is, in order for 4 photons to reach each beige square, the number of photons must be quadrupled for each yellow quadrant 9 times and for each green quadrant 16 times.

Since we are talking about the number of photons, the exposure parameter that needs to be modified is mAs and the formula that determines the change is:

$$\frac{mAs1}{mAs2} = \left(\frac{d1}{d2}\right)^2 \qquad (7)$$

Practical rule:

EA = 100cm	140cm	180cm
mAs	2 x mAs	4 x mAs

All above comments on the effect of exposure factors on radiological density apply when only one exposure parameter changes. However, it is not difficult to realize that we can enhance, reduce, or compensate for density changes due to one parameter with similar changes in the other exposure factors.

9.2. Contrast contrast

Contrast contrast is the difference in density between two adjacent points. The difference in density in adjacent areas of the radiological image allows the perception of anatomical structures.

The difference in density (contrast contrast) between adjacent anatomical structures must be at least sufficient to reflect different shades of gray. Two adjacent points on an x-ray rendered in the same shade of gray represent a structure for the human eye. In other words, an area of sufficient density with no difference in shades of gray is displayed homogeneously as if it corresponds to an anatomical structure. An area of uniform density in the image shows uniform behavior with the useful beam of the corresponding portion of the anatomical subject. When there are differences in the behavior of the anatomical elements of the subject towards the useful beam, then different densities result in the image.

The larger the density differences (contrast contrast) between adjacent areas or anatomical structures, the more easily they can be perceived by the human eye.

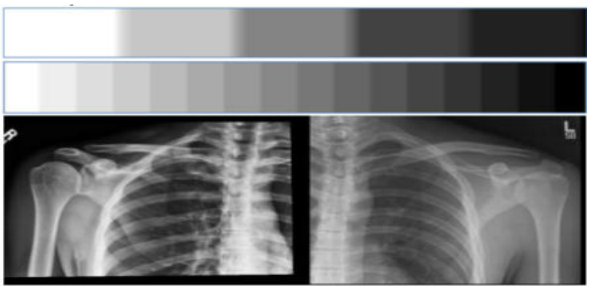


Figure 41. The difference in density (contrast contrast) between adjacent anatomical structures must be at least sufficient to reflect different shades of gray. Two adjacent points on an x-ray rendered in the same shade of gray represent a structure for the human eye.

An X-ray image may have a high or low SA. This is determined by the number of shades of gray it contains.

An X-ray with a high SA contains a few shades of gray between white and black (density values of about 0-4 for the human eye). This means that the density differences between the shades are large (= large SA).

A low SA x-ray contains many shades of gray between white and black (density values around 0-4 for the human eye). This means that the density differences between the shades are small (= small SA).

The level of SA (contrast contrast) that is desirable for each area of the body depends on the composition of the anatomical structure and the quality of the radiological beam (kV). The outgoing radiographic beam directed to the detector contains classified information that forms the primary, invisible image and reflects the physical SA of the anatomical structure of the kV.

Satisfactory depiction of the anatomical areas of the body that cause many gradients of attenuation of the useful beam is best when low SA techniques are used, while areas of the body with low gradients of attenuation of the useful beam are better represented by high SA techniques. Chest imaging has different requirements from limb or breast imaging for SA.

The image recording system always increases the physical SA of the anatomical subject to another degree.

The TA (radiologist technologist) decides which are the appropriate exposure factors that will give a satisfactory SA to the radiograph depending on the anatomical features of the area and how he should modify his technique accordingly. Satisfactory radiographic density is necessary to assess the CA on an X-ray. When the density of an x-ray as a whole is unsatisfactory (over- or under-exposed x-ray), then SA is not estimated.

9.2.1. Factors affecting contrast contrast

The physical SA of the anatomical subject depends on:
1. The thickness
2. The atomic number
3. The density

The above characteristics of the composition of the anatomical subject determine to what extent it will become a photoelectric or scattering effect during the interaction of the radiation with the anatomical subject. Tissues with a high atomic number absorb radiation more intensely (photoelectric effect).

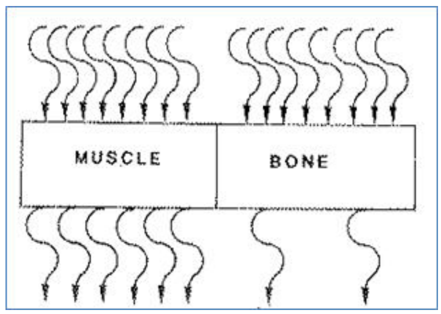


Figure 42. The absorbance between muscle and bone.

Anatomical structures with wide variety in composition show high physical SA, such as, e.g., the thorax that causes the full range of possible interactions from almost no absorption (pulmonary parenchyma) to significant absorption (bone). In contrast, anatomical structures with small fluctuations in radiation behavior have low physical SA, such as, e.g., the breast that has no air or bones, which lead to extreme fluctuations.

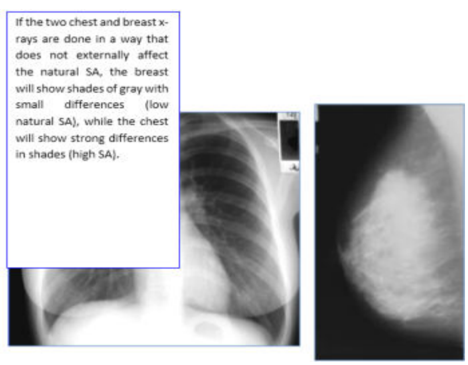


Figure 43. The anatomical structures with natural SA, the breast will show shades of gray with small differences (low natural SA), while the chest will show strong differences in shade (high SA)

TA can not affect the physical composition of the anatomical subject.

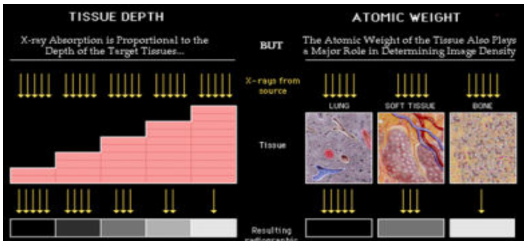


Figure 44. Tissue Depth Vs Atomic Weight.

The thicker and denser the anatomical subject, the more likely the scattering interactions are to produce photons that will reach the radiological film. The higher the atomic number of a structure, the greater the chance of a photoelectric reaction.

The quality of the radiological beam (kV) affects the SA of the radiological image. When we talked about the interactions between radiation and matter, we described the effect of kV on the probability of a photoelectric effect or scattering. We said that as the quality of the beam increases, the probability of a photoelectric effect decreases and scattering prevails.

1. The ideal radiological image is that formed by the absorption of photons (photoelectric effect) and the passage of photons (penetration).

2. Increasing the kV reduces the SA because it reduces the possibility of a photoelectric reaction.

3. When the penetration of photons (passage) increases, a total of fewer photons are required to achieve the same density, so the photoelectric reactions are even less (15% rule).

4. In addition, the increase in kVp multiplies the scattering photons. The scattering photons that reach the detector clearly increase the radiological density, but this density attaches to the image without providing anatomical information (fogging), like a curtain that does not allow us to see what is happening behind it. This density caused by scattering photons results in a further reduction in the SA of the radiographic image.

5. X-rays require a minimum value of kV (permeability) such as to allow a sufficient number of photons to reach the detector to obtain the correct density.

6. From the above, it appears why there are ideal values of kV for each anatomical area and this is why we do not use kV to adjust the density of the radiological image but the mAs.

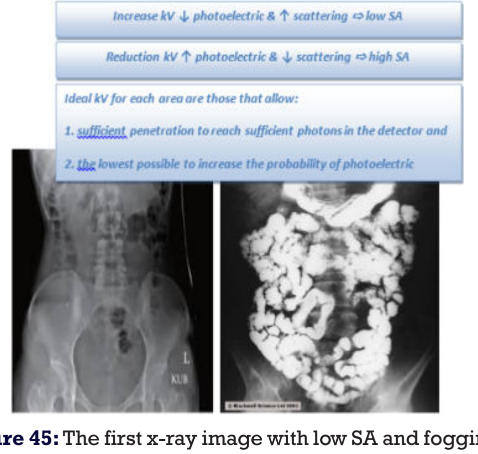


Figure 45: The first x-ray image with low SA and fogging and in the second x-ray image high SA of barley meal for high absorption of photoelectrons.

Other parameters that affect the CA of an X-ray are: the use and characteristics of the antiscattering diaphragm, the size of the radiation field, the objective distance (subject-detector distance), the detector and the processing of the chemical or digital image.

The SA of the anatomical subject can be changed with contrast media.

10. The radiological film

The radiological film is placed in cassette bearing Reinforcement Plates (EPs). In almost all applications except mammography, two OPs are used (one on each side of the cassette), so the film must be double coated, if it must have a photopathic coating on each side. The film captures the image based on the differences that the primary beam has undergone when passing through the anatomical subject and which exist in an invisible form in the patient leaving beam that falls on the cassette.

Films vary in size as do cassettes. The most common options are 18x24cm, 24x30cm, 30x40cm, 35x35cm, 35x34cm. The size of the cartridge to be used is selected depending on the size of the anatomical subject.

The films also show differences in their construction characteristics, as we will see in more detail in sensitivity. Usually now, in order not to make mistakes, each radiology department chooses a type of radiographic film (usually together with the one provided by the manufacturer OP) for general use and a type for mammography.

10.1. Structure

The double layer film can be seen in the cross section below: Notice that the base of the film is its thickest layer.

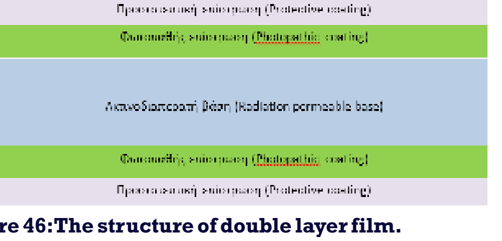


Figure 46: The structure of double layer film.

The active ingredient of the radiological film is silver which is in the photopathic coating in the form of crystals mainly of silver bromide. In a much smaller amount, silver iodide crystals are placed that facilitate the absorption of light emitted by the OPs. Silver bromide crystals are less sensitive to X-ray radiation and very sensitive to visible light and specifically to the wavelength of blue. The exact composition of the photopathic coating is a construction secret. The distribution and shape of the crystals also differ.

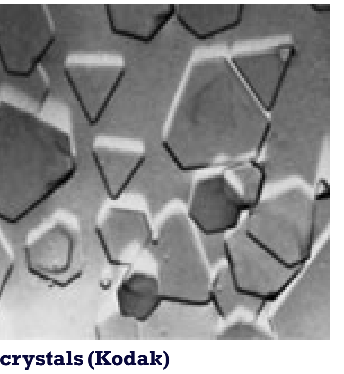


Figure 47: T-crystals (Kodak)

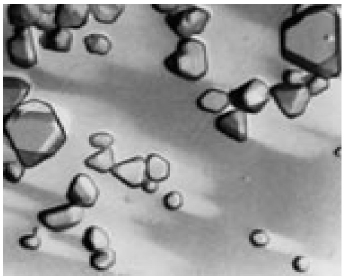


Figure 48: Common crystals

The base of the film is usually painted with a blue dye that facilitates reading.

10.1.1. Latent image

The term latent image refers to the image that exists in the film after the radiological exposure and which is not visible. The chemical treatment performs two roles: a) it makes the latent image visible (radiological image) in the process of appearance and b) it makes the radiological image permanent in the process of fixation.

The way in which the radiological image is created on the film is not known. There are several theories from which Garnier-Mott theory seems to best interpret the latent image formation process.

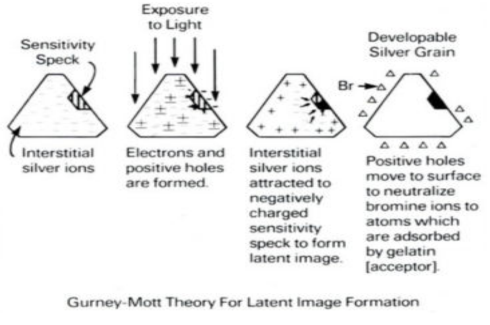


Figure 49: Gurney-Mott Theory For Latent Image Formation.

The more light an area of the radiographic film receives, the more latent image centers are created in it.

The creation of the latent image is attributed to the presence of centers of sensitivity on the surface of the crystals. These are areas of electron attraction and subsequent neutralization of silver atoms, where they are converted into latent image centers.

In practice, what we need to remember is that the silver in the photopathic coating in the form of silver bromide crystals is converted to metallic silver Ag 0 which is black. The higher the concentration of metallic silver (black grains) in the area of the x-ray, the higher the OP.

ONLINE PRESENTATION OF RADIATION IMAGE FORMATION

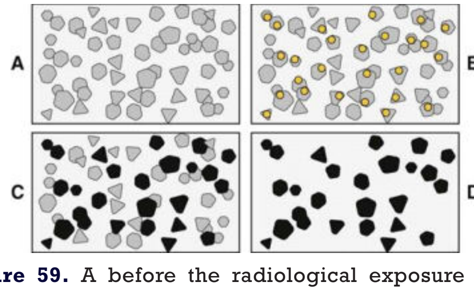


Figure 59. A before the radiological exposure of the photopathic coating, there are many silver bromide crystals B, after the radiological exposure, those crystals that have adequately detected the light contain a small amount of metallic silver in the center of sensitivity (which is not enough to see the image) but is enough to be information of the latent image.

C, during the chemical treatment, the appearance completes the reduction of the crystals that have latent image centers (yellow crystals in B) so that all silver contained in them becomes metallic (black grains).

D, in the next stage of the chemical treatment, the fixation removes all remaining silver bromide so that there is no possibility of another change of the OP by the light so that the radiological image becomes permanent.

10.1.2. Types of radiological films

Direct exposure films: these are films used in industry and exposed to radiation without OP. Dentists' intraoral film is also a direct exposure film.

Film for use with OP: it is the most widely used, it is more sensitive to light and less to radiation than the direct exposure film.

It can be double coated or single-coated film. The double layer film is used with two OPs. The single-layer film is used with an OP in mammography. Single-layer film has other uses such as computed tomography, magnetic resonance imaging, and ultrasound. Single-film films are also used in nuclear medicine, X-ray recording and laser printing. Single-layer films have a colored layer (absorbent layer) on the back of the base that absorbs light that passes through the photopathic coating so that no image is reflected from the reflection of this light back to the photopathic coating during radiological exposure or light used by other printing methods. The absorbent layer is removed during film processing.

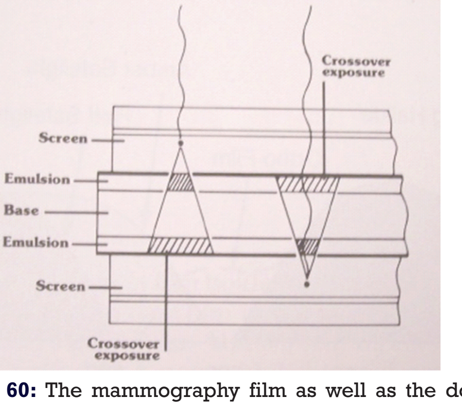


Figure 60: The mammography film as well as the double coated films have a blue colored base. In the rest of the films, the base is clean and looks transparent.

10.1.3. The characteristics of the radiological film

The characteristics of each film that stand out with the speed, contrast, and exposure range. In addition, the films are characterized by their size, color sensitivity, and exposure of the remote photopathic coating to a double-layer film.

The color sensitivity of the film must cover the emission spectrum of the OPs to which it is exposed. This condition is called spectral coupling and is necessary for the film to be able to make most of the light produced by the OPs and therefore to obtain the maximum OP. Therefore, we distinguish between blue and green films. In case there is no spectral coupling, the resulting OP will be lower than expected. Based on the color sensitivity, the light of the dark room is also selected, so that for the short period of time in which the radiological film is exposed to it, no perceived OP develops in the film. The appropriate light for the dark room is either red or the color of amber. Laser films require complete darkness due to their color sensitivity.

Crossover exposure is found in double-coated films exposed to two OPs. This is an exposure of the photopathic coating (PV) to light coming from the remote OP after passing through the proximal PV. The result is a reduction in clarity as shown in the figure. To avoid this, the manufacturers place a dye behind each photopathic coating (absorbent layer), which absorbs the light that passes through it.

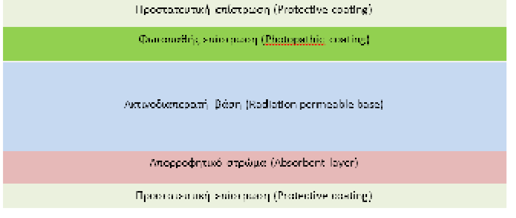


Figure 61: Single-layer films have a matte side (photopathic coating) and a glossy (absorbent layer).

10.2. The basic elements of the reinforcement plates

Reinforcement plates (OP) are located inside the cassettes. They contain fluorescent crystals that convert the energy of photons -X into the energy of visible light photons which exposes the radiological film. Fluorescent crystals are chemical compounds that emit visible light when exposed to X-ray photons. The reason that OPs are used is radiation protection. Their use allows the development of a satisfactory optical density (OP) of the radiographic film with much much less mAs than would be required to produce the same OP with direct exposure (without the use of OP). The main disadvantage of using OPs is the reduction of clarity. When OPs are used, the film is mainly exposed to the visible light they emit (99%). Only 1% of the OP developed by the radiological film is due to the direct effect of X-ray radiation on it.

10.2.1. Illumination

It is called the emission of visible light by a substance when it is irradiated with ray - X. Fluorescence, which in our case is desirable, is the emission of light only during irradiation. Phosphorescence is the emission of light that lasts even after the cessation of irradiation.

10.2.2. Structure of Ops

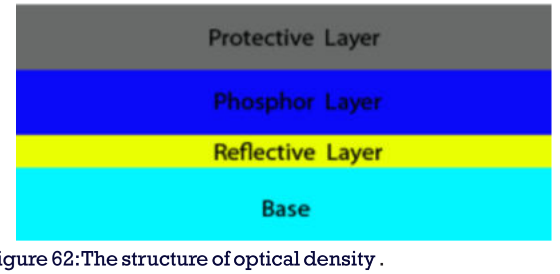


Figure 62: The structure of optical density .

The protective layer is made of plastic.

The fluorescent layer is the active layer of the OP containing fluorescent crystals. Sometimes a dye is placed between the fluorescent crystals that reduces the degree of light scattering that reaches the film. OPs are made accordingly with either an absorbent or a reflective layer.

Light is emitted by the crystals isotropically. The purpose of the reflective layer is to direct all light produced towards the film. Without the reflective layer, about 50% of the emitted light reaches the film. The fact that the film uses a large percentage of the emitted light has the advantage of radiation protection, but the disadvantage of reduce contrast clarity since the photons undergo greater diffusion.

In OPs that have an absorbent layer (dye layer), the light that reaches is absorbed and is not directed to the film. This has the advantage of less diffusion and therefore better image clarity and the disadvantage of lower OP since not all photons are used and therefore reduced radiation protection.

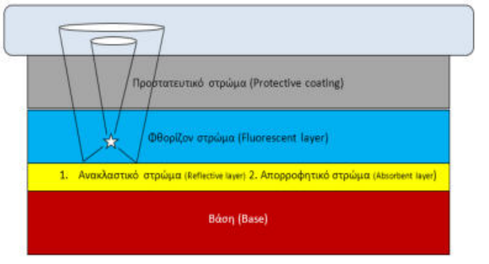
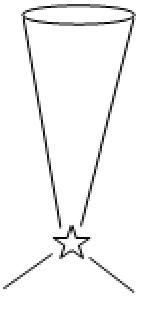


Figure 63: The optical density contains the fluorescent crystals.

The base is made of polyester or hardboard. Provides stability to the fluorescent layer.

In almost all applications except mammography, the cartridges contain two OPs and are used with double-layer film. In the case of mammography, an OP is used which is located on the back of the cartridge. The single OP is combined with a single coating film. When the film is placed on the cassette, the photopathic coating (the matte side of the film) must be in contact with the OP.



10.2.3. The characteristics of Op

Type of fluorescent crystals. Rare earths are now widely used in the construction of the fluorescent layer of OPs. These are items with atomic number 57-71 with difficult and expensive extraction. In clinical practice, they have replaced calcium tungsten because they are more efficient at producing light than radiation. Because rare earth crystals are more efficient, they achieve high speeds with satisfactory clarity.

The light emitted by the crystals can be blue - violet or green depending on the type of crystal. This information is very important because there must be spectral coupling to the film to be used. If there is no spectral coupling, the OP to be developed will be lower than expected as previously discussed.

OP speed. The purpose of using OPs is to reduce the radiation dose to the patient (radiation protection). Fluorescent crystals act as amplifiers of the X-ray effect by converting it to visible light. Therefore, the TA (radiologist) can use significantly lower mAs to achieve a specific radiological density. The ability of the OP to produce visible light is the speed of the OP. In the same radiological report, a fast OP produces more light than a slow OP.

The speed of the OP can be expressed either by the amplifying factor or by the relative speed. The amplifying factor of OP is described by the equation:

$$Enhansing\ factor\ = \frac{Exposure\ without\ OP}{Exposure\ with\ OP} \qquad (8)$$

The amplifying factor shows exactly the extent to which the patient is exposed to radiation when OPs are used. When the rate of OP increases, the required radiation dose decreases and the radiation dose to the patient decreases and vice versa. The relative speed of the OP results from the comparison of OP-film systems with each other based on the light (OP) they produce when they receive a specific dose of radiation. The amount of light produced by an average velocity OP of tungsten calcium is given the relative velocity value of 100. For the same exposure, an OP with a velocity of 200 will produce twice as much light and an OP of velocity 400 will produce 4 times as much light.

For the same exposure, as the speed increases, the amount of light produced by the OP and the OP developed also increases.

The equation that connects the velocity with the required mAs is:

$$\frac{mAs1}{mAs2} = \frac{OP2}{OP1} \qquad (9)$$

With this formula, we can calculate the change in mAs that is necessary to achieve the same OP with OPS of different speed. It goes without saying that when we apply this equation, the other exposure parameters must remain constant. The most commonly used OP speed is 400 because it ensures adequate radiation protection and acceptable clarity.

The speed of the OP is a structural feature and depends on many factors such as the size, density of the crystals, and the thickness of the fluorescent layer. Speed as mentioned is also affected by the presence of a reflective layer or absorbent layer.

From the above, we can understand that when 2 OPs are used in a cassette, the speed increases in relation to the use of one OP because the 2 plates produce about 2 times more light from one for the same dose of radiation.

10.2.4. Relationship between OP speed and rendering of details in the radiological image

OPs are used for radiation protection and perform this job extremely well. Radiation protection, however, is achieved at the expense of rendering the details in the image. When activated, a fluorescent crystal produces visible photons in all directions. As a result, the light of a crystal is scattered over a larger area of the film than would be affected by the X-ray photon if it fell directly on the film. The result of this diffusion is a reduction in the performance of the details in the radiological image. This qualitative characteristic of the radiological image is measured by the dummy of the marginal resolution and determines the smallest distance between two adjacent structures that allows us to see them separately and not as a structure. Clarity is expressed in line pairs / mm.

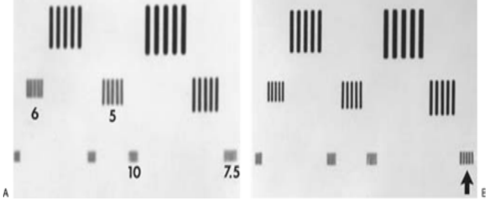


Figure 64: The presence of an absorbent layer increases the clarity while the presence of a reflective layer reduces the clarity as shown in the figure.

10.2.5. Maintenance of OPs

OPs should be cleaned regularly. Finger fat attracts dust and dirt that can be portrayed as technical errors. A special antistatic liquid is used that gently wipes with gauze.

Another important point is the good contact EP-film. When there is bad contact, additional ambiguity is created in the specific area of the film. Check this by wire mesh x-ray. Areas of poor contact are dark in the image. The cassettes are numbered so that it is easy to find one that has a problem.

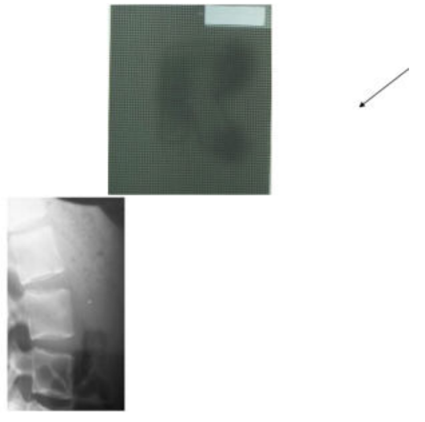
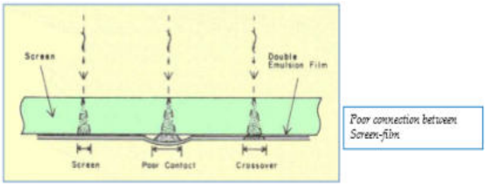


Figure 65: Poor IP-film contact in the "black" areas. "Skoupidaki" in the OP.



11. Shading media

Contrast contrast media are tools that enhance the contrast due to the physical properties of the anatomical subject.

Shading media are materials used to artificially increase contrast. These materials are duly injected (eg, intravenous infusion, ingestion, etc.) into organs which by standard radiological techniques are insufficiently differentiated from neighboring anatomical structures.

The contrast media used in X-ray imaging are classified into two broad categories:

- Materials of high atomic number (positive contrast media) eg, barium (Z = 56), iodine (Z = 53), which create contrast contrast through a photoelectric effect, ie, they absorb photons and do not allow them to reach the image detector, producing " shading "in the area where they are concentrated, and
- Low density materials such as room air, oxygen, and carbon dioxide, which create a contrasting contrast due to their very low density (gases), which drastically reduces the possibility of interaction with the photons of the radius beam, producing a "clearing area".

In both cases, the areas where the contrast medium is concentrated will show large differences (in terms of optical density) in relation to their environment, if there is an increase in the contrast medium.

11.1. Barium x-rays

Barium x-rays are performed using barium as a contrast agent to examine the upper and lower gastrointestinal tract. When barium is ingested, it outlines the upper digestive tract allowing the doctor to check for abnormalities, such as an ulcer, tumor or an obstruction of the duct (narrowing of an artery). It also allows the imaging of motor abnormalities of the esophagus, stomach, and small intestine.

For the examination of the lower gastrointestinal tract, barium can be inserted into the anus and intestine using an enema. Barium enema allows the imaging of the mucous membrane of the anus, the large intestine, and usually a part of the small intestine. The test can help diagnose diseases such as polyps, colon cancer, Crohn's disease, and ulcerative colitis.

Preparation. You generally need to fast or stay up all night before the test. To get the barium you will be asked to drink a liquid like chalk, which may have been flavored, to have a pleasant taste. If a heavy enema is to be performed, a laxative will probably be given the night before to prepare the bowel. An enema may also be needed for cleansing one or two hours before the test. With barium enema, barium is injected into the anus. Although we will have a strong desire to get rid of it, it is important to keep the barbell until the test is completed.

The examination. After the barium mixture has coated and filled the crypts of your digestive tract, x-rays are taken that reveal a clear picture of the shape and condition of these organs. An X-ray is also used to show the path of the barium. This device uses a fluorescent screen to convert X-ray images into visible light. The radioscope can also provide conventional x-rays at any time during the examination.

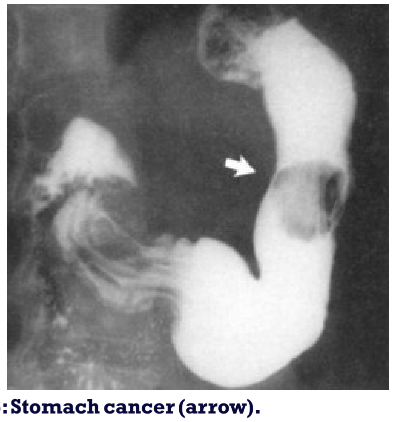


Figure 66: Stomach cancer (arrow).

For a clearer picture of the stomach, you may be asked to take a powder or pill that releases air into your stomach. The air will enlarge the stomach to give a more detailed picture of the organ.

During the examination of the intestine with barium, the doctor can place in different positions and press the abdomen, as the barium will flow along the intestine. It will try to push the barium into the small intestine. Sometimes the radiologist may blow air into the bowel to get a better picture of the fine features of his contour. This is practically effective in detecting very small polyps and bowel changes associated with ulcerative colitis or Crohn's disease.

Side effects. Barium is excreted in the faeces and generally causes minimal side effects. May lead to temporary constipation. For this reason, a laxative is often recommended after examination of the small intestine with barium . Barium enema is known to occasionally worsen ulcerative colitis or rarely lead to bowel perforation. It is possible to eat normally immediately after the test and you will probably be advised to drink plenty of fluids for the rest of the day. For many days after the examination, the stool may be slightly pink, as you will excrete the barium residue from your gastrointestinal tract.

12. Exposure of pregnant women to radiation

Examinations or treatment of pregnant women with ionizing radiation are avoided during pregnancy. However, there are cases of pregnant women intentionally or unintentionally exposing themselves to radiation for medical reasons.

Voluntary:

(a) for health reasons, in the context of a diagnostic test or treatment using ionizing radiation.

Voluntary exposure of pregnant women to ionizing radiation for health reasons should be carried out, if it is medically justified, and the necessary protection measures are taken during its realization.

b) in the context of her professional employment, e.g., medical and paramedical staff working in radiation departments.

Involuntarily:

It concerns cases where women of childbearing age are examined (and rarely treated) with ionizing radiation, ignoring the pregnancy status. This can happen either because the pregnancy is at a very early stage or because the possibility of pregnancy has not been adequately investigated. Involuntary exposure should be avoided.

Prior to exposure to ionizing radiation for medical reasons, any woman of childbearing potential should ask the referring physician, radiologist, nuclear physician, radiotherapist, dentist, or laboratory staff about the possibility. In any case, the woman must inform the doctors and the laboratory staff about the possibility of pregnancy.

In case of suspicion of pregnancy, the medical procedure involving irradiation should be postponed until the next menstruation (if this postponement is medically acceptable and does not endanger the woman's health) or if the pregnancy test is preceded by an indication is negative.

If the woman has not noticed any delay in her cycle, the diagnostic test / treatment can be performed normally. It is noted that contraceptive methods, such as the contraceptive pill or contraceptive coil, do not eliminate the possibility of pregnancy.

The 10-day rule (exposure to ionizing radiation only during the first 10 days after the start of the last menstrual period) may apply, but is not necessary in the case of low-risk diagnostic tests for the fetus (e.g. X-ray of the chest, limbs, head, etc.).

In case of confirmed pregnancy and before performing a diagnostic test / treatment, you should:

- To investigate the possibility of applying alternative diagnostic or therapeutic techniques with lower or zero radial load for the fetus (eg, ultrasound, magnetic resonance imaging)
- to investigate the possibility of postponing the examination or treatment for postpartum, if this is medically acceptable, weighing the risk and benefit both for the pregnant woman and the fetus.

If the postponement of the diagnostic test or treatment is not medically acceptable, estimate the expected dose in the fetus and take appropriate measures to minimize it. It should be noted that dose minimization measures should in no case limit the effectiveness of the examination or treatment. This is achieved as follows:

- In radiological examinations: Limitation of the number of shots, reduction of radioscopy time, appropriate selection of projections, appropriate configuration of the radiation field, use of appropriate examination protocols, etc.

- In nuclear medicine examinations: Careful selection of the administered radiopharmaceutical procedures for accelerating the biological excretion of the radiopharmaceutical and application of special examination protocols.
- in radiotherapy / radiotherapy: Careful assessment of the dose that the fetus will receive, specially treatment planning, to minimize the dose in it.

13. Professional responsibilities, duties & obligations of Radiology Technologists (TE & DE) in medical imaging departments

1. Generally

The object of the Radiologist Technologist of TE & DE category in Medical Imaging departments is the execution of a specific medical order, to visualize the requested part of the patient. Diagnostic information with the lowest possible radiation dose to the patient.

Important care of the radiologist is the comfort and safety of the patient from electrical, chemical, or mechanical hazards, which is achieved:

a) by recognizing all physical and psychological factors that can affect the patient b) their proper management by the radiologist, to eliminate or drastically reduce their effects on the patient during the examination. The Technologist Radiologist bears the part of the clinical responsibility for the patient to the extent that corresponds to him, and which is determined by his education, his specialization, his professional experience but also by the policy of the department in which he works. The overall clinical responsibility for the patient lies with the physician.

Utilization of all imaging or therapeutic possibilities provided by the technological equipment is the responsibility of the radiologist.

For this purpose, the Technologist Radiologist, performs checks of good operation and efficiency of the technological equipment and keeps the results of the checks in a log book. If there is a discrepancy in the performance or operation or damage that is presumably significant, then the radiologist is responsible to call the competent technical team to repair the deviation or damage. In the workshop, the radiologist gives the necessary information that will lead to the fastest and most economical restoration of the operation. After the completion of the restoration or maintenance work, it is the responsibility of the radiologist to make the necessary technical checks to ensure that the intervention of the technical workshop was successful and the efficiency of the equipment has returned to its previous state. The Radiologist has the responsibility to protect both himself and the other employees and the population from any kind of danger: mechanical, electrical, or chemical. He is particularly responsible for the chemical hazards that may result from fumes or release into the environment from the film processing chemicals.

2. Radiologist & Radioprotection Technologist

The Radiologist, working in a department with Ionizing Radiation must be able to know, understand, and apply all rules and regulations of radiation protection. He must be informed of any new modifications or changes or additions to the legal framework governing radiation protection in diagnostic and treatment departments in Greece and the European Community and take it into account when practicing his profession.

His constant concern is to keep the radiation doses of the patients and the population at the minimum possible level without affecting the diagnostic or therapeutic result, according to the principle of Optimization (ALARA'S PRINCIPLE). Because of his field of work, the Radiologist Technologist must utilize this important principle daily. That is why its role in radiation protection is remarkable. The Radiation Technologist should never allow improperly trained ionizing professionals to use machines for medical purposes without his presence.

3. Special tasks of Radiologists in imaging

It is responsible for the perfect representation of the requested molecule of the patient's body requested by the clinician. For this purpose, it places the patient and the equipment in a suitable position, taking into account both the physical condition of the patient and the capabilities of the equipment.

Selects the exposure factors that shape the quality and quantity of the radiation dose, to reflect what is required by the medical instruction. He chemically processes the received films in stable and fully controlled processing conditions, which are ensured after a quality control of the imaging device that he performs daily. This process also includes the preparation of the film's refreshing solutions, which is his responsibility. He makes sure that the x-rays taken from each patient carry all necessary data and information that will be needed for the medical opinion.

In the exercise of his profession, the information that he requests from the patient or that comes from the patient without the will of the radiologist, constitutes medical confidentiality, which the radiologist must observe. Prepares the x-rays received for use by the medical staff.

4. In the Department of Nuclear Medicine

- They register and store the moving radioisotopes in the special crypts as well as the radioactive residues.
- They have the responsibility to prepare diagnostic and therapeutic solutions of radiopharmaceuticals, determine and measure their dose, in collaboration with the Physical Hospitals.
- They adhere to the Radiation Protection Regulations and in case of radioactive contamination inform the radiation protection managers.
- They perform the measurements, record them, and bring them to the attention of the responsible doctors.
- They take care of the excellent quality of the IN VIVO examinations using the appropriate method in combination with the modern technology. In case of any problem, they inform the physicists of the hospitals.
- They take care responsibly for the correct registration of all medical records that concern the patient and the examination that was performed.
- They are responsible for the proper operation of the Department's showroom.
- They control and monitor the special areas for therapeutic doses and perform radiation protection measurements, in collaboration with the Radiation Protection Officers.
- They take care of the supply of consumables in collaboration with the doctors of the Department.
- They take care of the supply of consumables, reagents in collaboration with the person in charge.
- They supervise the cleaning and tidying of the devices, instruments, etc. of the laboratory.
- The number of the above graduates per c-Camera depends on the needs of the hospital.

5. In the Department of Radiotherapy Oncology

- They are responsible for the implementation of the patient's treatment plan, as predetermined by the Heads of the Department, according to the principles of dosimetery for each specific case.
- They monitor the operation of the machines and in case of any failure, they update the fault book of the relevant unit.
- Collaborate in the construction of protective blocks and

molds according to the plan of radiotherapy.

- They take care of the correct registration of all medical records that concern the patient and the examination of the radiotherapy that was performed.
- They meticulously observe and utilize the conditions of the Radiation Protection Regulations.
- They help in practical dosimetry measurements.
- They expose platelets, blood plasma, and other elements of the human body to radiation, serving other departments of the hospital or Research Centers, after the consent of the Department of Radiation Oncology.

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