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ORIGINAL RESEARCH PAPER

Radiology

PRINCIPLES &FUNCTIONS OF CONVENTIONALS & DIGITAL X-RAYS IMAGING SYSTEMS IN DIAGNOSIS

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ABSTRACT

Digital radiography (DR) is an advanced form of x-ray inspection which produces a digital radiographic image instantly on a computer. This technique uses x-ray sensitive plates to capture data during object examination, which is immediately transferred to a computer without the use of an intermediate cassette. The incident x-ray radiation is converted into an equivalent electric charge and then to a digital image through a detector sensor. Compared to other imaging devices, flat panel detectors, also known as digital detector arrays (DDAs) provide high quality digital images. They can have better signal-to-noise ratio and improved dynamic range, which, in turn, provides high sensitivity for radiographic applications. Flat panel detectors work on two different approaches, namely, indirect conversion and direct conversion. Indirect conversion flat panel detectors have a scintillator layer which converts x-ray photons to photons of visible light and utilise a photo diode matrix of amorphous silicon to subsequently convert the light photons into an electrical charge. This charge is proportional to the number and energy of x-ray photons interacting with the detector pixel and therefore the amount and density of material that has absorbed the x-rays. Direct conversion flat panel detectors use a photo conductor like amorphous selenium (a-Se) or Cadmium telluride (Cd-Te) on a multi-micro electrode plate, providing the greatest sharpness and resolution. The information on both types of detectors is read by thin film transistors. In the direct conversion process, when x-ray photons impact over the photo conductor, like amorphous Selenium, they are directly converted to electronic signals which are amplified and digitised. As there is no scintillator, lateral spread of light photons is absent here, ensuring a sharper image. This differentiates it from indirect construction.

1. Introduction

The illustration is based on the evaluation of images taken with special machines. Machines use different forms of energy, which interact with matter and therefore the human body, resulting in this interaction to create some form of signal. The sum of these signals composes a picture of the internal organs of the body and their abnormalities. It is necessary to know the images rendered by the normal organs, in order to be able to identify any deviations from the normal. The gradual acquisition of experience in deviations from the normal leads gradually to their responsible evaluation and final diagnosis.

The forms of energy used to create an image are electricity, which is involved in the composition and operation of all machines, electromagnetic radiation, which is the basis of Radiology and Nuclear Medicine, sound in the form of ultrasound, heat, which used in thermography and magnetism in the form of magnetic resonance.

Rontgen, Professor of Physics at the University of Wurzburg, has long experimented with cathodic rays, which for the last 10 years of the last century have been a field of extensive research for physicists. On the night of November 8, 1895, he observed fluorescence on the surface of a cardboard plate coated with platinum barium each time a current passed through a cathode ray tube. Repeat the experiment several times, changing the position and distance of the cardboard from the lamp and covering the lamp with black cloth, cardboard and wood. The phenomenon was repeated each time. From the first moment he realized that it was some form of rays. In the following days he continued his experiments feverishly, inserting various materials between a lamp and a fluorescent surface. When he put his hand in, he noticed a faint image of his bones reflected on the fluorescent surface. He later persuaded Ms Rontgen to rest her hand on a photographic film cassette and let current flow through his lamp for 15 minutes. The result startled Mrs. Rontgen when she saw the bones of her hand on the plate, but she added to Rontgen another piece of information about the properties of X-rays, as he called them.

Shortly after Rontgen's discovery of radiation, Becquerel discovered uranium radioactivity and isolated the Radium element from the Curie pair. Thus, within a few years, the birth of a new science took place. Radiology, which is the name given to this science, is one of the newest medical specialties and yet in the hundred years of its life and now it has revolutionized the diagnosis and treatment of many diseases, especially malignancies, it has created new data, it has helped in the understanding and way of teaching anatomy and physiology and has become the research instrument of many other branches of science, quite unrelated to Medicine.1.1. The Basic Radiological Machine

Modern radiological machines are complex and in many places use the most advanced technology. But the basics can be relatively easily explained and understood.

The lamp is glass, air-vacuum and has two poles. At the cathode of the lamp there is the 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 220 V 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 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). In order to adjust the potential difference at the poles of the lamp at will, in order to select the desired energy of the resulting rays, an autotransformer is inserted.

The electric current we use is alternating current (alternating current, AC), which, as it is 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 successive 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 phase of the current. That is, each of its poles becomes alternately positive - negative. By construction, however, the lamp has a permanently positive pole, the rise and a permanently negative, the descent. Alternating the poles would result in damage to the lamp. The avoidance of this alternation is done by rectification of the current (rectification), ie removal 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 cablesare special high voltage cables with special covers. The lamp is immersed in oil for thermal insulation.

2. X-rays

Fluoroscopy is done by studying the image created on the radiographic screen (screen). This panel is made of lead (glass with lead quantity) for precautionary purposes and has been coated with a fluorescent substance when exposed to Ro rays, usually barium cyanide platinum. The panel is mounted on a metal frame and attached to the lamp, located behind the transparent radiology table. This band has a mechanism for receiving and moving cassettes with films of different sizes, so that it is possible to take spot films during the X-ray. To prevent the patient from getting too much radiation, and because Ro-ray tubes can not be used at high currents and voltages for more than a few seconds, the X-ray is performed at low current, usually in the order of 3-4 mm ampere (3–4 milliamperes, (mA)). However, this results in the fluorescence intensity of the panel being so low that the retina must be completely adjusted to the darkness to perceive the image. Good eye adjustment requires staying in the dark or using special glasses for about 20 '.

X-ray, as mentioned above, has a major drawback. The eyes are adjusted to the darkness, so now the vision at low light intensity of the painting is done only with the sticks. However, the sight with the sticks is insufficient to recognize details of the image. In order to be able to perform X-rays in light without adjusting the eyes in the dark, it is necessary to significantly increase the X-ray intensity.

Today we have the light intensifier (image amplifier, image intensifier), which consists basically of an air vacuum cathode ray tube, the cover of which is coated with a fluorescent substance. The beam of radiation passing through the patient falls on the fluorescent substance, and the image formed is converted into an electron beam, which, after being significantly amplified, is converted back into an image. The image is then displayed on the screen of a CCTV device. In that way:

- Enhances the brightness of the image up to X 10,000 compared to the original. Thus, the X-ray is done in the light and with full exploitation of the vision with the cones, without the need to adjust the eyes in the dark,
- The diagnostic accuracy is increased, so that one can see many details that are impossible to study in the classic X-ray table.
- The radiation dose to which the patient and staff are exposed is reduced up to 10 times.
- Avoid losing almost 20 minutes that the eyes need to adjust to the darkness.
- Working in a lighted space has a favorable psychological impact on the patient, who is not obliged to enter a dark, unknown and inhospitable space.
- With the image amplifier it is possible to comfortably monitor the examination by third parties (other doctors and students).

An important advantage of using an image amplifier is that, with the light in the chamber, the doctor can perform various manipulations, impossible in the dark. It is possible, for example, to use needles and catheters. This self-evident possibility created Invasive Radiology, which means performing various manipulations for diagnostic or therapeutic purposes, under imaginative guidance.

The image can be permanently captured on X-ray, photographic or cinematographic film. We can also videotape the image (video - tape) replacing the cinema with a television camera. In this way, the image can be studied on a receiver (monitor) in the same space of the machine or anywhere else, using a closed circuit. The method has been used for a more detailed study of the examination and the findings and for follow-up, for discussion and teaching purposes, by more physicians in the office, in the lecture hall or in the amphitheater.

The radiological table, where the patient is placed for examination can be of two types:

- The horizontal radiology table is a permanent stationary construction with a surface made of radiopaque plastic material, where the patient lies. The cassette with the film can be placed on the bench, under the part of the body we are examining (eg chin, hand extremities, foot extremities, etc.). Most often, however, the cassette is placed in a special drawer below the surface of the bank, and is immobilized. Above the cassette, inside the drawer there is the Bucky anti-diffusion diaphragm. The beam of rays starts from the ray of light above the patient, passes through the body of the patient, through the Bucky diaphragm in the film inside the cassette. Some companies make the horizontal table with the possibility of a slight inclination to the head, to create a Trendelenburg position (supine position) or to the feet to place the patient in a half-lying position. The surface of the table can be moved horizontally, in the direction along the longitudinal (head - legs) or transverse (right - left) axis. In this way the patient's many movements are avoided and the minor corrections in its correct placement are made with movements of the table. The surface is then immobilized with electric brakes.

- The reclining radiology table can be moved from the upright position to the reclining position and beyond, to the Trendelenburg position, ie with the head at a lower level. This table is connected to the X-ray panel or the image amplifier system. The movements of the panel are synchronous with the movements of the X-raylamp, located behind the table. That is, the radial beam, from the hearth of the lamp, passes through the radial permeable surface of the table and the body of the patient and ends up in the X-ray table or the image enhancement system. The surface of the table can be moved, with a special switch, up or down or right-left.

During the passage of X-rays from the body, diffusion is created with the Compton effect, with the result that rays reach the X-ray plate from different directions. This, of course, creates a diffuse tan of the film, resulting in a significant loss of clarity and detail of the images. To exclude the rays that fall sideways in the film, we use the Bucky diaphragm.

This diaphragm is a mechanical component, in the form of a plate, consisting of alternating strips of very thin lead and radiopaque material and placed between the subject and the film. The Lead sheets converge in the direction of the lamp, with the result that the main (primary) beam passes between the Lead Plates, through the translucent material, because its rays are carried parallel to the Lead Plates.

The secondary (scattered) radiation carried in different directions is absorbed by about 80%, hitting the Lead. The anti-diffusion diaphragm is set in motion in a direction perpendicular to the strips when exposed to the rays, because otherwise thin shadows would be permanently captured by the lead plates.

The anti-diffusion diaphragm is a permanent part of the radiology table, ie it is located in a horizontal plane. However, there is also the Bucky upright where this diaphragm is in a vertical position and is a necessary tool for obtaining x-rays in an upright position (chest, sinus x-ray, search for free gases in the abdomen, joint study, etc.).

Various other accessories are used to further improve the radiological image and protect the patient. Indicatively, we mention the use of filters, which are placed in front of the Ro ray lamp. The filters absorb the soft rays, which are harmful to the superficial tissues and thus the beam hardens, ie it becomes relatively richer at shorter wavelengths.

Fluoroscopy is the creation of an image on the X-ray board. The main advantage of X- ray is the possibility of functional study of the organs. Under the fluoroscopic screen we monitor the respiratory movements of the diaphragm, the movements of the periphery of the heart and the large vessels of the chest, the mechanism of ingestion in the area of the hypopharynx and esophagus, the movements of the stomach and intestine, etc. . During the radioscopy, we can give infinite positions on the patient's body, lie down on the table, etc .. Radioscopy, in short, is a method for dynamic studies. It is also often used to guide the needle for puncture of a cavity or solid massfor biopsy, fluid examination or evacuation, especially in the chest. Its main disadvantages are two:

- It is a subjective method that depends on the mood of the moment of the examinee and
- Relatively large dose of rays received by the patient. This dose has been significantly reduced with luminosity enhancers, but it is still an inhibitory factor for the reckless use of radioscopy.

The dynamic study of various organs is done with various functional tests. A good example is the administration of a fatty meal for the functional study of the gallbladder or the taking of x-rays of the bladder during urination.

Sometimes, we get stereoscopic shots of certain organs. Two shots are taken with a small movement of the lamp on the surface of the film, as is actually done with the vision of our two eyes. Then, with a special machine, where the two x-rays are placed or with the eyes after some practice, the two images are composed and one can see the molecules stereoscopically, that is, in three dimensions.

When we want to study a molecule after the introduction of a shadow substance, e.g. in angiography, regardless of the bone involvement, we can use the subtraction technique. We get a plain x-ray, called a mask, and a second x-ray, in exactly the same position after the shadow substance is inserted. The two images are synthesized with the digital imaging system. The molecules present in both images, before and after the injection, e.g. bones and soft tissue, neutralize each other and project the elements that exist only in the second x-ray, e.g. the sketched vessels.

3. Digital X-ray

3.1. Flat Panel

The flat detector is a thin square sheet-film with ordered crystals (TFT). The sheet- layer is structured with pixels (picture elements, image elements as building blocks) and each pixel corresponds to a photodiode, which converts the incident light energy into an output electronic signal.

Because the TFT detector is sensitive to light radiation (and not X-rays), the presence of a scintillator such as CsI (cesium iodide), which converts incident X-rays into light, is necessary.

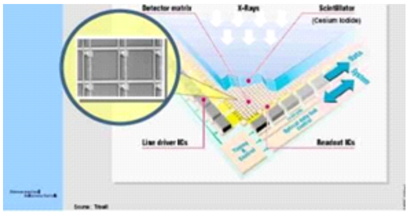

Figure 1. Flat detector technology is based on Csl and an active pixel matrix of amorphous silicon.

The flatbed detector replaces the image amplifier and optical device in imaging systems and directly records the range of radiographic images. On X-ray, the size of the pixel is usually larger than that of the X-ray. Some systems, to cope with both roles, have small enough pixels (100 to 150 m) for X-rays, but also have the (electronic) ability to combine 4 pixels into one (larger: 200 to 300 m) to make also suitable for X-ray.

The flat detector is smaller, lighter, there is no air vacuum tube, no electron beams, no optical device systems. The Quantity Detection (QDE) efficiency of the flatbed detector is much improved over that of the image amplifier.

3.1.1. Digital imaging device

It is a video recording device (slow scanning and good resolution), whose electronic output signal is digitized and stored in computer memory.

Alternatively, unified load devices (charge coupled device, CCD camera) with 10242 or 20482 pixel matrices are used.

CCD detectors are solid state and are usually made of electronically based silicon integrated circuits. CCDs act as photodetectors (converting visible photons into an electric charge) and therefore require scintillation material such as amplifier plates to convert X photons into visible photons.

But since CCDs usually have a much smaller surface area, a fluorescent substance with a large surface area is first used to capture the X photons and then optical fibers lead the visible photons into a matrix of many CCDs.

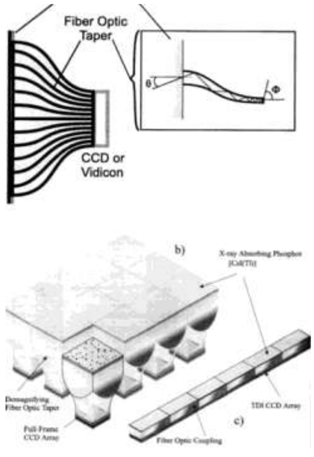

Figure 2. Charged coupled device CCD camera.

The X-ray image can thus be stored electronically on a computer for use with digital image processing methods.

Digital imaging devices allow the immediate presentation of the image on a television screen, as well as the direct retelling of previous images, so that the invasive doctor can compare and decide.

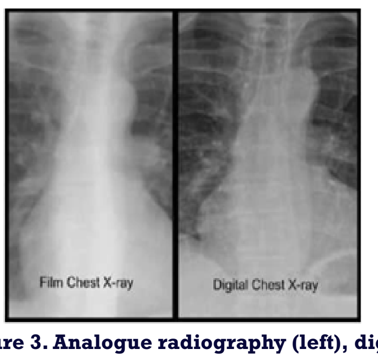

Figure 3. Analogue radiography (left), digital radiography (right).

3.2. Peripheral recording units

3.2.1. Photo-spot cameras

They use 100 mm photographic film and "see" directly the output amplifier output screen. The surgeon presses with a foot a special ground switch for as long as he wishes to archive the corresponding images (this is a two-button switch. The first is pressed while the X-ray lasts and the second is for recording). The ground switch is connected to the optical device that directs part of the optical beam to the camera, but at the same time the X-ray generator is activated, which produces additional radiation pulses. For a field of 23 cm of the amplifier, an exposure dose of 75 to 100 R per image is recorded.

Due to the direct visual contact, the resolution of the photographic film is the same as the corresponding one on the output screen of the image amplifier.

3.2.2. Cine-Radiography cameras

They adapt to the visual layout and have the ability to record sequential images in 35 mm film very quickly. They are preferred by cardiologists to "capture" fast movement. They start at 30 images per second and reach 120 or even more. They require very short pulses of radiation that can be produced by special generators. The two systems are synchronized with great precision. The X lamp load is large and significant amounts of heat are generated. The exposure of the input screen of the image amplifier for a diameter of 23 cm, is 10-15 R per image. Digital CCD cameras are often used.

3.2.3. Spot-Film Devices

There is a suitable socket in front of the image amplifier and when the invasive doctor deems it necessary, he presses the special switches.

A classic radiographic cassette (reinforcement plates and film) is transferred from a side case to the "field of action" and records the X-ray beam as it exits the body of the subject. The cassette is accompanied by an anti-diffusion grid and its exposure is controlled by the automatic adjustment system.
A 30 cm-30 cm cassette can record 4 smaller images 15 cm-15 cm or a larger one, with a slightly better resolution than the corresponding image amplifier.

1.2. Function of X-ray

With the help of computers, X-ray generators and entire imaging systems have gained the flexibility to adapt to the requirements of Medicine.

3.3.1. Continuous X-ray

It is the basic mode of operation. The X-ray beam is produced continuously and the current in the lamp ranges from 0.5 to 4 mA depending on the thickness of the subject.

The output of the images is at a rate of 30 per second, ie each image lasts 33 ms (1/30 of a second). Any movement during this time will blur the image, but is an acceptable situation for most exams.

3.3.2. Pulse X-ray

The X-ray generator produces a series of short pulses. It can give 30 pulses per second and each pulse lasts 10 ms, with a current of 6.6 mA. Such an adjustment would give the same exposure rate to the examinee (as in continuous radioscopy), but with a shorter exposure time (10 ms instead of 33 ms), while also reducing the blurring of the image by any movement of the examinee.

During an examination, there are intervals that even 7.5 images per second are enough, such as e.g. when advancing the catheter from the femoral artery to the aortic arch.

At the rate of 7.5 images per second and as long as it lasts, the dose to the examinee is reduced to a quarter (7.5 / 30 = 25%). Of course, at the low rate of image production, the screen will flash, but even this is treated with the help of digital technology that intervenes and "freezes" every image on the screen for as long as needed, but giving the feeling of spasmodic movement.

3.3.3. Representative image (Frame Averaging)

X-ray systems provide very good time resolution and this feature makes them clinically useful.

However, the speed in the display adds noise and most of the time a compromise is desirable, which is achieved with the method of the representative image. Theimages are digitized and go through a "average" real-time process. Running the algorithm, however, takes time, reducing the time resolution. The compromise is closer to one side or the other depending on the application and the preferences of the user.

The average image tool for a series of images can significantly reduce the dose to the subject and is often used in portable X-ray machines that have lamps with more limited capabilities.

The algorithms are many, but they have in common the idea of adding each new image to the immediately previous one, with a weighting factor that is adjusted on a case-by-case basis. Therefore, the place of real images is occupied by "normalized" images, depending on their immediate past (the older the image, the lower the coefficient of gravity)!

3.3.4. Keep the last image

When the invasive doctor lifts his foot off the ground button and stops the X-ray, the system keeps the last image on the screen. The last image is digitized and remains on the screen until the doctor presses the switch again to continue the procedure. It is a convenience that gives the doctor time to concentrate, gives the opportunity to any attending trainees to discuss and keeps the radiation dose of the examinee at a low level.

3.3.5. View anatomical map

It is another convenience for the invasive doctor's work to be provided by a suitable computer program. It is essentially a software extension of the previous paragraph. There are two variants of it.

The system of the first variant is equipped with two TV screens placed close to each other, in the position that best serves the doctor in his work. One screen is the basis of the X-ray, while the second can transfer (and "freeze") a representative image of the procedure, which clearly shows the anatomy of the area (eg the length of the vessel in which the catheter is performed , immediately after contrast medium injection).

The system of the second variant is more advanced and transfers the "frozen" image-map, below the image of real time, as a background. This facilitates the doctor's manipulations as he carefully pushes the catheter inside the vessel.

1.3. Clinical act

For each type of application, a different X-ray machine is selected, except in the case of small clinics, where a, as flexible as possible, X-ray system is called upon to contribute to different types of examinations.

3.4.1. Gastrointestinal unit

It usually has a bulky bed for the examinee, which can be rotated horizontally or vertically. The video amplifier is either above or below the bed. Both systems of the image amplifier and the X-ray tube is covered with radiation shields. Spot film or photo spot camera are available .

3.4.2. Peripheral Angiography Unit

It is characterized by a flexible in its movement, bed. With simple movements the doctor can "drag" it to many positions of the horizontal plane, so that in the irradiated field, the area of interest under study is constantly located.

The movement of the amplifier-lamp system is also flexible, which can be rotated around the examinee. They are mounted on a C-shaped arm (C-arm) or U (U-arm), which can follow a circular trajectory, as well as change the rotation level (for rear, front, side, oblique views). A contrast agent is always available.

3.4.3. Cardiology Unit

It mainly performs cardiac catheterization, coronary angiography and coronary artery angioplasty.

They have an even more flexible amplifier-lamp system than their peripheral angiography counterpart and prefer an image amplifier up to 23 cm in diameter to the standard 30 cm peripheral angiography. They require cine cameras (with film or digital).

A. Two-level X-ray system

This machine has a bed, but two integrated amplifier-lamp systems, each of which operates in a perpendicular, relative to the other, plane. With this it is possible to simultaneously record the front and side view e.g. immediately after contrast medium injection.

That is, the time of the examination and the amount of the contrast agent that is administered to the patient are reduced, which usually causes intolerance.

When the system is pulsed, there is a special electronic circuit that synchronizes the two generators, so that the scattered radiation from one is not displayed on the screen of the other.

B. Surgery and Intensive Care Unit

They are equipped with C-arm mobile X-ray machines, usually with a small diameter image amplifier.

3.4.1. Angiography

Angiography is the imaging of blood vessels that use a water-soluble X-ray contrast agent, injected into the bloodstream of arteries (arteriography) or veins (venography). For the lymphatics, contrast oils are used.

Angiography is used to investigate normal and pathological conditions of the vascular system for stenosis and obstruction or aneurysmal enlargement. Additional arteriovenous malformations (AVM) and arteriovenous fistulas (AVF) or sources of bleeding are investigated by angiography. These complications will arise mainly from local problems, such as hematoma, aneurysms and arteriovenous fistulas, etc.Nowadays, images taken primarily with digital removal techniques (DSA digital angiography), one-shot or fast series can be obtained with Fast Movie Converters, in Cine mode (Cine angiography for coronary arteries) or as digital video recordings directly from the screen. image enhancement.

Injection of contrast medium for arteries and veins can be injected either directly through needle puncture or through transdermal use of an angiographic catheter often made of polyethylene, polyurethane or nylon.

A specific terminology comes from 1) the instrument to be displayed, e.g. coronary, cerebral, renal, hepatic angiography, 2) the area, e.g. aortography, peripheral angiography, 3) by the method selected at the desired organ site or area, e.g. direct arteriovenous / venography or arteriovenous catheter / venography, and 4) the choice of access.

Angiographic studies are usually performed under local anesthesia. After filtering the skin and tissues around the artery or vein to be pierced, a small incision is made in the skin, and the artery is pierced with an angiographic needle. For percutaneous catheter insertion, the Seldinger technique is used.

REFERENCES

1. Physical & Technological Principles of Radiology. I. Kandarakis. Ellin Publications, 1998.
2. http://aktinologiaradiologia.blogspot.gr/2012/07/aktinologiaradiologia.blogspot.c om (last access 18th of February 2022)
3. Diagnostic approach to breast cancer with mammography, ultrasound and color Doppler. Konstantelou Eleni.
4. Notes V: Computed Tomography CT, MRI, PET. Stelios Orfanoudakis, Costas Marias. September 2003-February 2004.
5. HY 571 -Medical Imaging. Costas Margias.
6. Medical Imaging Systems. Koutsouris D., Nikita K., Pavlopoulos Th. Tziola Publications, 2004.