ANNALS OF FACULTY ENGINEERING HUNEDOARA
– International Journal of Engineering
Tome XI (Year 2013) – FASCICULE 4 (ISSN 1584 – 2673)

[1.] Ionuț Daniel RĂDUCAN, [2.] Gheorghe CIOBANU, [3.] Viorel ȚANDEA

EVOLUTION OF RADIO-IMAGERY TECHNIQUES AND DEVICES

[1-3.] VASILE GOLDIS WESTERN UNIVERSITY OF ARAD, ROMANIA

ABSTRACT: In almost every field, changes occur permanently, old theories and practices are demolished, being replaced with newer and better ones but maybe no other medical branch has evolved so dramatically as radiology and medical imaging.
KEYWORDS: radiology, imaging, evolution, history

INTRODUCTION

From ancient times, there was the issue of investigating the structure of the matter but without investigation possibilities, it was assumed that there are elements of minute dimensions, which by assembling would lead to the diversity and unity of the matter. The theories of the ancient scholars Anaxagoras, Leucip and Democrit (6th- 5th century BC) was the starting point that took shape along the history of science. The diversity of the material world is explained by the combining a finite number of atoms. During that period of time because the theory had no experimental support, for a long time these theories were considered only speculations.

In time, the global industry has evolved and were deepened the theories which had as central point the atom, this time on scientific and experimental grounds. Thus the theory that the structure of the material world is based on the atom was the focus of attention of some great scientists such as Galileo, Huygens, Newton, Gassendi, Bacon, Bernuolli, Lomonosov and used by chemists to explain a series of quantitative aspects of the chemical phenomena.

The first to observe the luminous phenomena that occur in a glass tube in which vacuum is made using an air pump, is the Abbé Nollet, in the eighteenth century. The tube had at both its ends a metallic electrode, both being in connection with one pole of a machine with electricity by friction. Typically, the air from the tube opposes resistance to the passing of the electric current, being a bad conductor of electricity. If one applies a high voltage at the tube's terminals, at some point zigzagging sparks unite the two electrodes. This phenomenon shows variable aspects according to the voltage applied to the terminals and according to the degree of decrease of the gas pressure in the tube.

Experimental data led to conclusions that demand a change in the way we look the atom. A series of phenomena suggests the existence of an internal structure of the atoms: electric sheath and core. Based on these new findings it was tried imagining some models of atoms such as: in 1902 Perrin describes the atom as a miniature solar system, in 1904 Tomson describes the atom as a sphere of positive electricity in which the electrons are floating, also in 1904 Nagaoka, describes the atom as identical to the planet Saturn in which the heavy core attracts the lighter particles that make up surrounding ring.

These models have been unsuccessful because from Maxwell's theory it follows that electrons which might revolve around a central core, would lose energy by radiation, which would cause them to gradually come closer and end up falling on the nucleus. In 1911 Rutherford goes back to the idea of the atom similar to a solar system after studying the deviation of the alpha particles when passing through layers of substance.

In 1895, Wilhelm Conrad Roentgen made a major discovery in the history of world science. Roentgen announced his discovery, and also the technique used to obtain the new rays called X, in his correspondence with friends and colleagues from Vienna, Berlin, Hamburg and Manchester.

Contested by some, praised by others, Wilhelm Conrad Roentgen took his place in history of physics as the man who discovered X-rays, which also bear his name. Roentgen was born in 1845 in Lennep, Germany, being the only child of a merchant and textile manufacturer. Thanks to his mother, who came from an old Dutch family, the Roentgen family decided to move to Holland when little William was only three years old.

In 1865, Roentgen enrolls in the classes of the Faculty of Physics of the University of Utrecht, but does not get the required number of credits to become a student and decides to go to Switzerland, where he is registered in the Polytechnic Institute of Zurich, after passing the exams. In 1869 he presented his doctoral thesis in Zurich and is appointed as assistant to the famous physicist August Kundt.

One of the most important moments of his life was the meeting with Ivan Pulyui, a physicist of Ukrainian origin, who provided the German scientist one of the lamps that he used to obtain what he called "X-rays". Roentgen discovered the rays bearing his name by pure accident, experimenting in his laboratory the effects of the discharge of high-intensity electrical charges through glass tubes filled with gas at very low pressures. Starting with 1895, when he discovered the X-rays, Roentgen spent the rest of his life almost closed in the lab, studying this phenomenon.

Roentgen was already studying the effect of the cathode rays which occur when electrical current passes through a highly rarefied gas. In November 1895 he found that if the tube through which the electric charge passes, is insulated with black cardboard to exclude any source of light, in the working conditions of a darkroom, a cardboard which has on one of its surfaces baric platinocyanide becomes fluorescent, even if it is located at a considerable distance from the tube. Roentgen went further and noted that the same phenomenon of registering the transparency of a body takes place using photographic plates.

On December 28th, 1895 Roentgen submitted to Physical-Medical Society of Wurzbrug the work called On a new kind of radiation, work which is the first document of study of X radiations and which contains two radiographs. The photographic clichés represented bones and the ring of a hand of his wife both symbolically representing the two orientations in the use of X-rays: diagnostic radiology in medicine and flaw detection in industry. The discovery of X-rays meant a true revolution, especially for medicine and biological research. Rays bearing Roentgen's name are commonly used today in the diagnosis and therapy of various disorders. In 1900 Roentgen was elected professor and director of the Institute of Physics of the University of Munich and in 1901 received the Nobel Prize for Physics. Roentgen continues his scientific activities and collaborates with electrical companies (Siemens) and brings improvements to tubes and devices.

It followed a time when these rays have conquered the world, each university seeking to procure such a device that can take pictures of the human body. Approximately one month after the presentation of Roentgen's communication, the Romanian scientist physicist Ph.D S.D. Hurmuzescu, who was then working in Paris in the physical research laboratory at the Sorbonne, together with Professor Benoit began to study the properties and effects of X-rays, with the helpf of an installation they improvised themselves. Still at the same time, Professor Gheorghe Marinescu used the same installation to perform radiography of some interesting cases (acromegaly).

In 1896 the physics laboratory of the School of Bridges and Roads in Bucharest are held the first demonstrations with X-rays in Romania under the leadership of Professor Many and also in this year the professor Hurmuzescu holds a lecture about the Roentgen rays. At the Coltea hospital, in the surgery department of Professor C. Severeanu, began in 1896 to make the first radiographs in our country and the results obtained have been presented at the International Congress of Medicine in Moscow in the year 1897.

In Iași in 1901 is made another installation for production of X-rays under the guidance of Professor Hurmuzescu as Director of Boarding High School in Iasi. At the same time, the radiology education has expanded and was organized better and better. At the Faculty of Medicine of Iasi, was appointed professor of radiology Emil Radu, and in Cluj Professor Dimitrie Negru, founder of radiological education in Transylvania and of the first Institute of Radiology in Romania. First complete treatise of Radiology: Diagnostic radiology, radio-physics, radiotherapy is published by Professor Dimitrie Negru. The history of Romanian radiology has passed mainly through the same stages, the same characteristics as in other countries, the level of the Romanian radiology being as high as in all advanced countries.

One year after the discovery of X-rays there is such a device in Romania and works began to appear that addressed general aspects, but especially the particular ones of the various systems of the human body: skeletal, digestive, etc. The center of these experiments apparently was Vienna, where many radiologists have risen, some of them paid with their lives working with existing equipment at the time, totally unprotected, some of them having malformed descendents. In their memory, in Hamburg was erected a monument to victims succumbed to X-rays.

Today we have a large variety of radio-imagery methods of exploration among which the most common and affordable in our country are simple radiological exploration methods and methods with contrast agent.

RADIOLOGICAL EXPLORATION METHODS WITHOUT CONTRAST AGENT

- ☐ *RADIOSCOPY is the simplest, fastest and cheapest radiologic method. It consists in examining the on the display of the Roentgen device, the images that the X-ray beam forms after it crossed a* *certain anatomical region, and it is based on the following properties of the X-rays: propagation in a straight line, penetrability, uneven absorption and fluorescence.*

The radioscopy provides us valuable data on the morphological appearance (overall, relationships, mobility, pain points of the organs) and functionally, dissociates the images.

The radioscopy must be performed systematically after a certain plan starting with the overall exam, continuing with the examination of certain regions, symmetrically and successively in different incidents. It should have a short duration in order to radiate as little as possible the patient and the examiner.

- *RADIOSCOPY WITH IMAGE INTENSIFIER AND TELEVISION. The progresses made in the field of electronics have resulted in an increase of the quality of this method of examination both by information infusion as well as a number of other advantages: it reduces the radiation dose by about 50%, providing ideal protection of the patient and the doctor, increase the brightness degree of the screen of 3,000 to 6,000 times as compared to the usual radioscopy, makes images that can be analyzed and interpreted in the daylight, highlights small lesions, the image can be sent to remote devices on TV sets which are in other rooms, the image can be recorded on radiographic film or magnetic tape with the possibility of later replaying.*

The image amplifier consists of a electronic tube which has vacuum inside and is equipped with two screens: the primary screen located at the entrance to the tube – consists of a fluorescent screen that converts X photons into light photons and a photoelectric layer that transforms light photons into electrons. These electrons are accelerated in an electric field of 15-25 kV and focused to the secondary screen which is of smaller size, but with a much higher luminous effect. The phosphorescent anodic screen form a smaller image than the section of the examined region, which is then reflected on a mirror from where it will be broadcasted to the television screen, to a photographic camera (ampliphotography) or recorded on film.

The development of electronics has led to electro-mechanization of the remote control examination maneuvers, which allows remote examination outside the room where the patient is located. The radiography is the radiological exploration method which is based on the property that X-rays to impress the emulsion of the radiographic films which it renders capable after developing to present the image of the object crossed by the X-ray beam.

RADIOGRAPHIC IMAGE

The photographic emulsion exposed to X photons is impressed and by developing it blackens. Thus the radiographic film can highlight the latent image contained by the beam of electrons emerging from the crossed body, blackened in the areas where radiations reach without being absorbed and remaining more transparent in those parts in which are projected formations which have absorbed the incidental photons fully or in a greater amount. Thus the photographic emulsion is impressed, and by developing it becomes darker the more radio-transparent are the material formations traversed by the beam of radiation.

The radiographic image is the negative of the radioscopic image because the elements opaque to the X rays appear bright (white) on the radiographs while the transparent elements give a dark image. Thus at the thorax level the lungs du their air content retain in a small measure the radiations – because the air and gases have a low attenuation coefficient due to their low density shall appear on the radiograph as darker images separated between them by the radio-opaque image of the mediastinal opacity.

For the abdominal organs the contrast is less obvious: are visible the images of the liver, kidneys and spleen, mainly due to the relative radio-transparency of a thin fat layer that surrounds these viscera (the fat tissue shows an attenuation coefficient lower than other soft tissues).

Chances intestinal and stomach are not visible if they are empty, if they contain a certain quantity of gas relative gets a radiolucent, absorbing a lesser extent visible photons segments X and becomes more or less their spread of mold cavities.

To make visible the natural cavities of the body radio-graphically, indirectly, one can chose to fill them with substances with a higher atomic number which are thus radio-opaque, constituting the so-called artificial radio-opaque contrast agents. Also, radio-transparent contrast agents can be used, filling the same real or virtual cavities with air or other gases.

- *TELE-RADIOGRAPHY. A typical radiography is made from the distance of 80 cm - 1 m. The distance between focus – and film of 2 m is considered the distance where the X-rays are parallel, obtaining an almost real image in shape, dimensions and structural details.*
- *RADIOGRAPHY WITH HARD RAYS OR WITH OVERVOLTAGE._This type of radiography is performed with 110 -150 KV and is used for the study the structure of complex images. Thus we can identify by fluid opacity a pathological process of the lung parenchyma (i.e.: we can identify a parenchyma tumor masked on the standard radiography by pleurisy), we can easily identify pulmonary vessels, bronchia, ganglions.*

- *THE DOUBLE EXPOSURE RADIOGRAPHY. Consists in performing two successive exposures on the same film. It is used to study the mobility of the ribs and the diaphragm by assessing their degree of movement in inspiration and expiration.*
- *DI-GRAPHY. It is a variant of the radiography with double exposure. The di-graphy requires the use of lead grid placed longitudinally which is interposed between the patient and the film. A first exposure is made while inhaling, then the grid is moved laterally, covering the exposed strips and then a second exposure is performed while exhaling deeply.*
- *POLY-RADIOGRAPHY. The poly-radiography is used for the assessment of movements of an organ (i.e.: the gastric peristalsis) and consists of making multiple exposures on the same film.*
- *SERIOGRAPHY. In case in which you have to study various aspects of a moving organ or the different phases of the same phenomenon that are in rapid succession, there special devices called seriographs which allow you to perform the same film two or more radiographs at longer or shorter time intervals.*
- *MEDICAL RADIO-PHOTOGRAPHY. Is a method of radiological investigation which consists in photographing the image obtained from the radioscopy, on 7/7 cm or 10/10 cm films.*
- *AMPLIPHOTOGRAPHY. Consists in making photographs of the radiological image from the image amplifier.*
- *STEREO-RADIOGRAPHY. The stereo-radiography is a radiological method that allows you to obtain in depth images. The technique consists in performing two successive radiographs in the same incidence moving the transverse tube 65 mm (interpupillary distance). The radiographs are examined simultaneously with a special optical device.*
- *TOMOGRAPHY. Tomography, stratigraphy and planigraphy are methods through which is made the radiographic representation of a single layer from the thickness of the body examined, as much as possible released from the overlapping of the images of the overlapped layers from plans. The method is based on using a device that allows you to print a movement of the radiogenic tube and radiographic film during exposure, the radiographed body remaining motionless. Tube movement is done on a circle segment (scanning of 20, 40, 60 degrees) whose center of rotation is located in the layer to be tomographied. By this method, layers which are located in the plane of the axis of movement are projected during exposure at the same point on radiographic film, while images of the layers located above and below interested plane are projected constantly in different points, which makes their images to be erased causing a diffuse clouding more or less blurred. Practical applications of tomography are numerous. Thus, for the thorax, any parenchymal cavities from the mass of a condensation that are not visible because they are covered by the anterior and posterior opacity, constitute the widest use. Other uses of tomography are to regard of the study of the petromastoid region for internal and middle ear, larynx, some urinary apparatus examinations and in other cases of bone pathology. Tomography can be performed in the frontal plane, sagittal. Although conventional tomography is still a valuable additional examination of the radiological investigation, in various pathological conditions, it is currently surpassed by computerized axial tomography.*
- *ZONOGRAPHY. It is a tomography performed with a small scanning angle 3-6 degrees thus obtaining the image of a layer several cm thick.*
- *COMPUTERIZED AXIAL TOMOGRAPHY (TAC) called the Anglo-Saxon terminology Computed Tomography (CT scan) and in French literature Tomodensitometrie, is a method of investigation which, although based on the use of X-rays does not produce a direct image by the emerging beam but through very numerous dosimetric measurements with mathematical processing of the data collected. It builds by calculation the radiological image of a traversal layer of the body examined. The method was developed in 1973 by English engineer Gotfray Hounsfield who presented his first results obtained by this method of skull and brain examination. Subsequently the technology of the devices has progressed rapidly and allowed for the exploration of the whole body, being presented in a continuous evolution. TAC, in comparison with the traditional radiography, allows highlighting of structures whose radio-opacity difference to the nearby tissue is so low that it cannot be evidenced by traditional radiological exams. In fact this is the advantage that revolutionized in recent years many chapters of conventional radio-diagnostic in some cases making unnecessary the use of artificial contrast agents.*
- *PANTOMOGRAPHY is a method of radiological exploration by which you get a panoramic image of all the teeth. The X-ray beam is selected by a slit and oriented to the dental arches passing through another slot and impressing the radiographic film. The patient and film rotate in opposite directions. The irradiation is minimal, only in the dental arches.*
- *ROENTGEN CINEMATOGRAPHY is made filming the screen of the image hardener. This method allows for obtaining cinematographic sequences with a frequency up to 100 photo frames / second, which is usually used in cardiologic radiology especially for the study of the coronary arteries or of the heart cavities.*

- ☐ *XERORADIOGRAPHY. It is an investigation method which is based on the property of X-rays to produce variations in electrical resistance of semiconductor crystals. Its image does not require photographic reproduction, it is obtained by Xerox processing. It uses an aluminum plate covered with a layer of selenium (it represents the support and tank of positive electrical charge). The region to be studied is traversed by the beam of X-rays and makes on the selenium plate a latent image which becomes apparent after applying a transfer powder composed of electronegative charged particles which are deposited according to the electric charge of the plate. This image is then transferred onto a sheet of paper.*
- ☐ *MEDICAL THERMOGRAPHY. At the skin level is projected infrared thermal radiation emitted by tissues and organs. They can be captured by an optical system, converted to electrical signals and electronically amplified. Further electrical signal transfer is done in the light which is registered on the fluoroscopic screen or on a polaroid film. The warm portions cause white images and the cold ones black. The thermography is very useful in dermatology, vasculopathies, malignant tumors exploration, rheumatic processes.*
- ☐ *ULTRASONOGRAPHY. It is an important method of investigation relatively recently introduced in medical practice. It is based on the use of ultrasounds which are reflected as echoes depending on the mechanical properties of solid and liquid tissues, proportionally to the penetration resistance (impedance of each organ). The ultrasounds are used for two important purposes: to achieve sectional imaging and for measuring blood flow velocities. The ultra-sonographic imaging technique is called ultrasonography. The most common type of speed measuring technique is called Doppler ultrasonic flow and Doppler ultrasound method.*
- ☐ *NUCLEAR MAGNETIC RESONANCE IMAGING is a method of investigation which is based on the physical phenomenon of rotation of H protons around its own axis which is called spin. In standby state the H protons in the human body are oriented anarchically. If we submit them to an intense static magnetic field acting outside the body at a low temperature, they become aligned with their parallel or antiparallel axis to the direction of the magnetic field. Under the action of another external field protons lose their orientation and alignment of returning to their original position of equilibrium, going through a pitching phase that consists of a rotating movement analogue to the movement of a spinning top during which they are emitting a resonance signal received by the detecting coils. The amplitude of the received signal is proportional to the number of nuclei in the sample. The protons of H that are seen better are those linked to water and fat. These two environments dense in protons appear white, bone (15% water) is black just as the lungs. Fluids in motion having moving protons also have very weak signsl. (Bottom-MRI images, abdomen, respectively cervical spine)*
- ☐ *POSITRON EMISSION TOMOGRAPHY. Some components of living matter O, C, N, by bombardment with cyclotron accelerated particles can be brought into the state of radioactive isotopes. So are born such artificial radioactive isotopes that have the property to emit positrons for a very short period of time. Encountering two electrons they produce 2 electromagnetic radiation (2 photons) which are propagated linearly in opposite directions. A system of detectors, two at each end of the axis activate when simultaneously hit by photons and record radiation. A computer records the number of emitting atoms, their density, location and duration of emission. The data obtained appear on a computer screen and are recorded on the computer.*
- ☐ *DIGITAL EXPLORATION. Acquisition of digital images consists in converting the image to numerical data a system called digital analog and bringing it back to the screen through an analog digital converter of the digital image stored on computer. The resolution of the image is limited to a number of points, horizontal and vertical data. The more points there are, the sharper is the picture. The image is defined by a number of shades of gray. Digital angiography is based on the phenomenon of numerical subtraction. It allows injecting a small amount of contrast agent into the vein, without the need for injections by intra-abdominal probes. Lately we are witnessing a rapid development of image creating medical devices, a real image making technology for which the best term seems to be that of medical imaging.*

RADIOLOGICAL EXPLORATION METHODS WITH CONTRAST AGENT

Radioscopy, radiography and computerized axial tomography allow highlighting some organs and pathological formations whose thickness and attenuation coefficient creates a natural contrast with surrounding tissues. This contrast can be increased or even created when it does not exist by means of the so-called artificial contrast agents. These are made up from elements or compounds with a specific weight, different from the one of the tissues examined and which, entering in virtual spaces or natural cavities makes a mold and produces images of an adequate opacity in the case of radio-opaque contrast substances or of a major transparency for radio transparent or gaseous contrast agents.

The contrast by opacity can be increased even in some organs or tissues by injecting the contrast agent in the circulation. By this method it can be highlighted firstly the opaque vascular branches and *then the organs or tissues by distribution of the opaque blood in the territory of the arteriolo-capillary of these structures.*

Contrast substances although they are not strictly speaking medicinal products as they produce no therapeutic effect, they must be known by all practicing physicians because in recommending their use for performing radiological examinations with contrast agents one must know the risks to which the patient can be exposed and assess the benefit that can be obtained from these examinations proportional to the risk that they pose.

The first attempts of using artificial contrast agents have started since the last century but only in 1910 was proposed using barium sulphate for the radiological examination of the digestive tract. In 1912 Sicard and Forestier introduced use of iodized oil for exploring the spinal canal. This substance was then used in making opaque the bronchial tree (bronhography) of the fistula ways (Fistulography), the uterine cavity (hysterosalpingography) and for other purposes. Currently soluble iodinated contrast substances are mainly used for making lymphographies and sialographies.

In terms of visualization of urinary excretory tracts it begins in 1906 when Voelber and Von Lichtenberg have obtained retrograde opacification of the ureter and pielouretereal cavities with colloidal suspensions of heavy metals; the urography obtained by intravenous injection of substances that are eliminated by the kidneys and that in this way render the urine opaque, thus visualizing the excretory pathways, was introduced into practice in 1928 by Binz and Rath.

A remarkable process in this method was obtained in 1953-1954 by producing tri-iodinated soluble contrast agents showing a higher contrast and better tolerability. These substances serve to render opaque the cardiac chambers and peripheral vascular system.

Rendering opaque the biliary ways is obtained by using compounds that are eliminated by the hepatic cell together with bile produced by it. After using series of such substances whose efficiency was moderate it was achieved a decisive progress in this field only in 1952, with preparations of tri-iodinated contrast agents, which could be administered orally without toxicity at the doses required and with a high contrast . A year later was also made an injectable contrast agent that secreted with bile after 15-30 minutes after injection renders opaque enough to be highlighted the biliary ways and the bile duct, and after an hour to be highlighted also the gallbladder.

Recently there have been introduced non-ionic contrast agents that are better tolerated by the organism, having a lower osmolarity.

CONCLUSIONS

Roentgen's discovery made it possible to create extremely sophisticated devices, but also new techniques for investigating any anatomical and functional element of the human body. There have been created devices designed for sections through the body, such as tomographs, and many other techniques and x-ray machines. The radiological devices to which computer systems for collection, analysis and image storage were built in, as well as all the methods based on the computer image diagnostic gave rise to radiology imaging. Over time this part of radiology has grown enormously and included other methods which do not use X-rays for diagnosis: MRI, ultrasound, positron emission tomography, etc.

ACKNOWLEDGEMENT

This work was cofinanced from the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013, contract no. POSDRU/107/1.5/S/77082 „PhD Scholarships Complex Training in Bio-Economy and Eco-Economy for Food and Feed Safety and Security in Anthropic Systems" - Vasile Goldis Western University of Arad

REFERENCES

[1] ANDREEA FLEANCU, GABRIELA SECHEL, LILIANA ROGOZEA, ALEXANDRU BĂNUȚĂ, MIHAELA BADEA , Începuturile utilizării radiologiei ca metodă diagnostic in Brașov, Sighișoara, Sibiu
[2] BRĂTESCU C., Istoria ocrotirii sănătății muncitorilor din România, Bucureşti, 1957
[3] HUTTMANN A., Trecut şi viitor în Medicina, Studii și note, sub redacția dr. G. Brătescu, Ed. Medicală, Bucureşti, 1981
[4] MULLER C., Die Rontgendiagnose des Ulcus pylori, in Festschrift an lasslich der XXXVII. Wanrderversamnlung ungarischer Aerzte und Naturforscher, Sibiu, 1914
[5] http://ssa5.tripod.com/id15.html
[6] http://www.timpul.md