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The biophysical modelling of the medical devices in the field of biophysics

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Abstract

In medicine we live the period of enthusiastic use of the models that use, one way or the other, various devices created and invented on the basis of theoretical knowledge of biophysics. Further on we will deal with only three directions: ultrasound application, computer tomography and magnetic resonance. Currently, the widest field of application of the ultrasounds in medicine is the one of exploration and diagnostic. The computer tomography (CT) used X rays to perform detailed images of the structures of the organism. A part of the scanner can be tilted, which allows taking images of the studied are in various positions. The images are memorized in a computer. The images of the computer tomography scanner can be taken before or after the administration of the contrast substance. With the MRI examination, very small lesions (1-2 mm) can be detected and there is the possibility of Multiplan representation. In the case of medical investigations using MRI, the body of the patient is placed on a horizontal table along a very strong magnetic field and with a coil another type of radiofrequency is used which subsequently is recorded. The first uncertainty relation: Living organism cannot be studied in the space, at any small or big dimensions because at the level of those subsystems or extrasystems the characteristics of life disappear. The second uncertainty relation: Living organisms cannot be studied in time, at any long or short intervals, because at the level of these time values the living system do not have the characteristics of life.

Keywords: Ultrasounds, Scintigraphy, First and Second Uncertainty Relations

Introduction

Any person is influenced by the social group it belongs to from the point of view of the role it has in the society and the conviction with which they apply this role every day. The society determines decisively the behavioural role that man has. There is a demand related to each person from the peer group to have a specific behaviour to correspond to a concrete situation. It is a demand that people behave specifically according to the concrete situation. In the society, during life man plays-consciously or unconsciously-different roles it commits to. The roles in which man appears depends on several factors: sex, age, family, occupation status, healthy-sick, common interests, etc.

The development of the personality takes place in the reciprocal interaction between the „I"-the person and the environment through communication in concrete situations [1]. For a balanced accommodation with the „I" they must interiorize the environment's requests, the opinions uttered and accept the sphere of conventional attitudes, hence, finally to be unanimous as the other. Through socialization his status in the environment interiorizes and the intrapsychological processes develop through the interpshychological interaction. The „I" which incorporated social attitudes determined by the cultural parameters is the product of individual development, which has the role of achieving an adequate behaviour, which is a psycho-homeostatic function [2].

The responsibility belongs to each individual because they are responsible for the facts they commit. The behaviour expected from us is in concordance with the social role and with the own conception about themselves.

Some Medical Devices in the Field of Biophysics

Undoubtfully, in medicine we live the period of enthusiastic use of the models that use, one way or the other, various devices created and invented on the basis of theoretical knowledge of biophysics [3]. We could talk in this sense even about a social-psychology of the huge number of researches in the entire world, fascinated to a great extent about the novelty that the exploration of these state of the art devices exerted on them. This expansion is common both to clinicians who manifest less reserve towards the application of this important biophysical factor due to the fact that it is at a certain distance from the fundamental data of the problem in comparison with the researchers.

Due to a high number of high tech techniques, today's physicians have to possibility to explore very thoroughly our organs, no matter how deep they are, obtaining an almost anatomical image of their anomalies. The classical radiological exams are at presents replaced by various techniques of medical imaging which use X rays (tomography), magnetic field (magnetic resonance imaging), ultrasounds (echography, Doppler) or radioisotopes (scintigraphy) [4].

Further on we will deal with only three directions: ultrasound application, computer tomography and magnetic resonance.

The history of use of ultrasounds starts in 1880 when the brothers Pierre and Jacques Curie discovered the piezoelectric effect, an electromechanical phenomenon in which, after the application of a mechanical pressure on certain crystals, on their sides appears an electric polarization [5,6]. The apparition of a mechanical deformation under the action of an electric field represents the reverse piezoelectric effect. The first trials of application of ultrasounds in medicine have been found by Wood and Loomis in 1927. The application in diagnosis of the ultrasound progressed after the year 1955 when John Wild and John Reis detected breast tumours and large intestine tumours with it. Then, it passed to the use in obstetrics and gynaecology. In 1958, Ian Donald highlighted ovarici cysts and managed to measure the biparietal dimension of the foetus's head and in 1960 Donand and Brown highlighted multiple pregnancies [7].

Currently, the widest field of application of the ultrasounds in medicine is the one of exploration and diagnostic. It is about echography, under its various technical aspects, as a method of visualising of some internal structures [8]. The ultrasounds being an oscillating elastic phenomenon which carries a radiant energy, the contact with a biological system produced all the phenomena characteristic to the interaction between a radiant field and a substance. A part of the energy of the ultrasound field is reflected differentially at the surface and at various depth levels by formations characterized by different acoustic impedances.

For the ultrasound testing, a gel or oil is applied on the skin in order to improve the propagation of the sound waves. A small hand operated device, called transductor is moved back and forth on the area which needs to be studied [9]. The transductor transmits high potency sound waves (situated beyond the human auditory spectrum) which are then reflected back to it. A computer analyses the sound waves and converts them in an image displayed on the screen of a monitor.The image produced by ultrasound is called sonogram, echogram or ultrasound scan. Photographs or movies of the ultrasound images can be achieved. The ultrasounds are used for the study of the organs and structures which are uniform or solid (like the liver) or filled with liquid (as the urinary bladder, the gall bladder).The mineralized structures like the bones or filled with air like the lungs cannot be seen on sonograms.

A great part of the therapeutic techniques using ultrasounds are based on their thermal effects. The chemical effects, extremely complex consist mainly in the acceleration of the biochemical reactions and break of some macromolecular structures.

At present, after the accumulation of a rich experience and perfecting of the device, the use of ultrasounds extended a lot, including various medical branches such as: internal medicine, urology, endocrinology, obstetrics and gynaecology, orthopaedics, neurology, cardiology, ophthalmology, surgery.

The computer tomography (CT) used X rays to perform detailed images of the structures of the organism. [10] During testing, the patient will be laid on a table connected to the scanner of the computer tomography, a big sized device with the aspect of a coreless cylinder. It will send impulses of X rays through the body of the patient. Each impulse lasts a second and form the image of a thin slice of the organ or area studied. A part of the scanner can be tilted, which allows taking images of the studied are in various positions. The images are memorized in a computer. The CT can be used for the study of any organ of the body such as liver, pancreas, intestines, kidneys, adrenals, lungs and heart. It can also study blood vessels, bones and marrow. An iodine paint (contrast agent) can be used in order to made the organs even easier to observe on the images of the computer tomography scanner. The contract agent can be used to study the blood flow to find tumours or to look for other problems. The contract agent can be administered iv or per os (orally), according to the desired test. The images of the computer tomography scanner can be taken before or after the administration of the contrast substance.

The first successful image of magnetic resonance was the paramagnetic experience performed by Zavoiski in 1944 in the USSR.

The magnetic resonance is a research method that deals with the study of the interaction of the nuclear magnetic and electronic moments with electrical and magnetic fields and with the transitions which take place between the energy levels resulted from these interactions.

1. The electronic paramagnetic resonance (RPE): The magnetic electronic moment of spin plus orbital.
2. Spin electronic resonance (SER): Spin magnetic moment.
3. Nuclear magnetic resonance (NMR): Nuclear magnetic moment.
4. The quadripolar magnetic resonance (QMR): NMR in magnetic field zero, which analyses the quadripolar nuclear magnetic moment.

We must specify from the beginning that in the MRI the experiments are performed only on the atoms of the nuclei and not on their electrons, so the information supplied refers to the spatial positioning of these nuclei in the chemical compound studied. [11] These nuclei have an intrinsic property called spin but in order to explain the phenomenology which lies behind this technique we must take into account the following physical aspects:

Any electrical charge in movement generated a magnetic field around it. The same thing happens in the case of nuclei (positive electric charges) when, due to the rotation around their own axis, a magnetic field is generated characterized by a magnetic moment μ, pro¬portional and of opposite sense than the one of the nucleus I. In the NMR the interest nuclei are those nuclei who have the value I=1/2 (1H, 13C, 15N, 19F, 31P).

If we place an atomic nucleus in an external magnetic field B0, then the magnetic moment vector will be able to be parallel

(I=+1/2) or anti-parallel (I=¬-1/2) with the direction of this field. We must specify the fact that energy of the anti-parallel system's energy is much higher than the energy of the parallel system and this difference is directly proportional with the value of the field B_0 (ΔE=μB/I).

If we irradiate the nucleus of a radiofrequency field on a transversal direction of the constant field B0, this field transporting an energy equal with ΔE, then the nucleus (the spin) will get excited passing from the energy state +1/2 in the energy state –1/2 characterized by higher energy.

But since in natural conditions any physical system tends towards an energy state as small as possible this nucleus will be relaxed by returning to the state +1/2 and issued in another field of radiofrequencies of whose parameters (frequency) information is obtained about the nature of the nucleus (position in the molecule, respectively the type).

With the MRI examination, very small lesions (1–2 mm) can be detected and there is the possibility of Multiplan representation. The images are obtained in sections, making possible the visualization of the nerves, fine vascular structures, articulations, bones etc. Sometimes it is necessary to inject a paramagnetic contrast substance for an optimal visualization of the affection detected. Usually the time for an investigation is 15–20 minutes (a segment-the spine, the knees) up to 60-90 minutes.

The MRI examination is recommended for the cranium, thoracic region, blood vessels, spine, bones, articulations, abdominal and pelvic areas.

The current moment, the period of enthusiastic application of the various devices would maybe find resemblance in the splash of use of radioscopy and radiography at the beginning of the XXth century immediately after the discovery of the roentgen rays. They soon started to show the negative effects on the human organism, so their use has been soon limited. Also, after the first uses of the radioisotopes in the biomedical research and therapy, medicine knew another morbid entity: internal irradiation, no less harmful than the external ones. The same opinion must be considered today in the problem of ultrasounds. As long as we do not know completely the methods of echography or the methods deriving from it, they must be recommended carefully and only when the problems appeared cannot be solved through other means.

An extremely important and incompletely studied phenomenon in these days in the biological systems is the cavitation produced through the application of ultrasounds. Transitory cavitation in the moment of breaking the bubbles which contain water vapours whose temperature reaches la 2.000°K, produces a shock wave which harms the cells and the macromolecular structures.

The CT uses X rays to achieve detailed images of the structures inside the organism. But the X rays are very dangerous for the living organisms, this is why the CT must be used very carefully. For example the patient could be allergic to the contract agent used.

In the case of medical investigations using MRI, the body of the patient is placed on a horizontal table along a very strong magnetic field and with a coil another type of radiofrequency is used which subsequently (immediately after passing through the body) is recorded.
Before the MRI the physical must be informed:
–If the patient is pregnant or not;
– If the patient has a pacemaker installed, an artificial limb, metallic rods or any other type of metal in the body (especial in the eye area), cardiac metallic valves, metallic clips at cerebral level, metallic implants in the ear or eyebrows or any other types of implants or medical prostheses (for example pump with injectometre); the physician must also be informed if the patient works with metals or if they had recently suffered blood vessels surgery;

✓ If the patient has an intrauterine device (IUD) this can deny the effectuation of the test;
✓ If the patient becomes agitated in closed (limited) spaces;
✓ If the patient has other affections such as renal dysfunctions with could counter-indicate the effectuation of MRI with contract agent;
✓ If the patient has any type of patch because the MRI can cause burns at the level of the region.

It is recommended that the patient be accompanied by someone for the case when sedatives are administered. The patient will sign a document saying that they understand the risks of the MRI and they agree to undergo the test. It is recommended to discuss this method with the specialist physician.

The mechanisms of the biological effect, especially those at distance in all three methods are incompletely known. Maybe these effects should be studied from the point of view of the stress factors, hence with non specific action. In order to asses the value of these three methods, we must compare it with other similar methods both from the point of view of the information obtained and the one of the risk factors.

Two Uncertainty Relations-in Biology
In 1925 Werner Heisenberg enounced the basic principles of a complete quantum mechanics. In this new context, he replaced the classic commutative variables with non commutative ones. Heisen¬berg's work marked a radical detachment from the previous attempts to solve atomic problems with the help of noticeable amount. Heisenberg said that it is impossible to determine simultaneously and with unlimited precision the position and the impulse of a particle [12].

The principle of uncertainty of Heisenberg gives a lower limit on the product of the standard deviations of the position and impulse of a system, specifying that it is impossible to have a particle with an impulse and a position arbitrarily well defined simultaneously. More precisely, the product of the standard deviations

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

Where $\hbar$ is Planck's constant. The principle can be generalized to many other pairs of amounts, except for position and impulse (for example, the angular impulse on two different coordinate axis) and it can be derived directly from the axioms of quantum mechanics.

In any case, it is now understandable that the uncertainties from within a system exist before and independently from the measurement and the uncertainty principle is hence independent from the observatory effect.

The measurements of the position and impulse effectuated on identical copies of a system in a given state will vary each of them according to a probability distribution characteristic to the system state. This is the fundamental postulate of quantic mechanics.

If we calculate the standard deviations Δx and Δp of the measurement of the position, respectively the impulse, then

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

Where $\hbar$ is Planck's constant.

More generally, given any hermitic operators A and B, and a system in state ψ, there are probability distributions associated with the measuring of A and B, giving the standard deviations $\Delta_\psi A$ and $\Delta_\psi B$. Then

$$\Delta_\Psi A \Delta_\Psi B \geq \frac{1}{2} \left| \left\langle [A, B] \right\rangle_\Psi \right|$$

Where the operator $[A,B] = AB - BA$ represents the switch of A and B, and $\langle X \rangle_\Psi$ represents the expected value. This inequality is called the Robertson-Schrödinger relation and it includes the principles of uncertainty of Heisenberg as particular case. It has been shown for the first time in 1930 by H. P. Robertson and (independently) by E. Schrödinger.

Unlike the examples above, some uncertainty principles are not direct consequences of the Robertson-Schrödinger. The most famous of these is the energy-time uncertainty principle. By applying the ideas of relativity restrained on the principles of uncertainty position - impulse a lot of physicists, such as Niels Bohr postulated that the following relation should exist:

$$\Delta E \cdot \Delta t \geq \frac{\hbar}{2}$$

But it has not been immediately obvious how should Δt be defined (because time is not treated as operator).

In our opinion, on the basis of the biophysical knowledge, biology there are two relations of indetermination for the living systems. The living systems are represented by organisms for which it is characteristic to appear as spatial-temporary coordinates, in a certain time (t_1) and in a certain place (x_1, y_1, z_1) and to disappear (they loose in their capacity the characteristics of the living) in a certain time (t_2) and a certain place (x_2, y_2, z_2).

The first uncertainty relation: Living organism cannot be studied in the space, at any small or big dimensions because at the level of those subsystems or extrasystems the characteristics of life disappear.

The second uncertainty relation: Living organisms cannot be studied in time, at any long or short intervals, because at the level of these time values the living system do not have the characteristics of life.

Conclusion

In such a moment, when new data are published in an avalanche, the researcher who dares to explore biophysics in all its amplitude can feel suffocated by the difficulty of the undertaking and can find insurmountable difficulties in the trial to separate the perenial facts from the amount of data and facts which do not have another signification than the one of illustrating a fashion, to be them contradicted by new data. Today it has become obvious that the study of the biological phenomena must be based on biophysical modelling. The achieving of this thing would help us better understand the vital processes and their directing mode. In order to advance in this direction, medical biophysics offers an important research tool. On the contrary, the neglecting of this tool weakens a lot the position of the researcher or makes the medical research impossible.

The book has been elaborated with double purpose: the obviously didactic one, of instruction of the medical students in the problems of contemporary biophysics and the other one to offer updated information necessary to the researchers and the physicians at various specializations. In the presentation of the material we started from the idea that the physician of the 21st century must be capable to keep pace with the extremely rapid development of science. This is why in the description of the phenomena we insisted both on their qualitative and quantitative side, we gave up the older theories in favour of the new ones, what we considered that allows the fundament of a modern scientific conception.

Any scientific monographic book is written using both a synthesis of the existing literature and the immediate experience coming from personal research. But is it self explanatory that both personal experience and the theoretical inclusion cannot have an exhaustive feature, especially in a science in which new data are brought no only from one year to the other, or from one month to the other, but from day to day; it is obvious why in this biophysics book personal research together with the one of the co-writers find a wider space.

Far from the though that such a book could include all the problems of the field it aims, it has been conceived in various purposes:

a) Sensitization of the scientist from the field of human medicine at the modern issued of biophysics;
b) The formation of a connection bridge between the ingenious modelling of biophysics and the epochal discoveries of the contemporary medicine;
c) The clarification of the current orientation in the so important problems of modern investigations which incited passionate debates in the past decades.

Before letting the reader elaborate their own value thought about the current state of biophysics and on the effort concretized in the current monography, we add that in order not to force the person interested only in certain parts and chapters discussed by this monography lecture the book from one cover to the other in order to understand the notions, the discussion of the matters studied is structured so that the reader can consult independently any chapter of the book.

In the past decades, in the wide field of medical biophysics continued to appear important cognitive and applicative progresses. Knowing the normal functionality and the factors of health maintenance, the mechanism of disturbance of the function state can be discussed, with the evolution in the deviated sphere of the disease generating pathologic and implicitly the recognition the prevention and the correct treatment.

The attempt to offer a panoramic image of the current knowledge of the wide field of medical biophysics, represents the conditions of the great progresses of the contemporary medical sciences, a more that brave an attempt. From here, the impossibility to present the adequateness and the inequality, insufficiency or even lack of many of the new general and specialized medicine knowledge in the material elaborated by us. Only solid medical biophysics knowledge ensures the starting base of the curative, preventive and recovery medical act.

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