Management in the Protection from Ionizing Radiation

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Abstract. There are numerous types and forms of endangering working and living environment, ranging from natural disasters to nuclear accidents. Challenges of the New Age determined that most of the countries reviewed its strategic decisions in the system of protection from ionizing radiation and nuclear safety and defined in a new way the threats, which could considerably imperil health of the population and national interests as well. Excessive radiation of the pouplation became a serious and actual problem in the era of increasingly mass application of ionizing radiation, especially in medicine. The goal of this work is to reduce the risk through using knowledge and exisitng experiences, in particular when it comes to ionizing radiation in medicine. Optimization of the protcetion in radiology actually means an effort to find the compromise between quality information provided by diagnostics procedure and quality effects of therapy procedure on one side and dose of radiation received by patients on the other. Criteria for the quality management in the protection from ioniizing radiation used in diagnostic radiology was given by the European Commission: European Guidelines on Quality Criteria for Diagnostic Radiographic Images, EUR, 16260.

KEYWORDS*: *Ionizing Radiation, Medicine, Radiology, Risk Management, Protection from Ionizing Radiation

1. Introduction

The effects of ionizing and non-ionizing radiation can be expressed directly on the radiated person by means of somatic effects or indirectly, on offspring, by genetic effects. Low dose radiation increases cancer and leukaemia probability (late somatic effects) and genetic impairments. Risk of the radiation is determined by monitoring of the health of people radiated by high dose radiation. In last 50 years, new instruments (radio telescopes, ultraviolet detectors) have considerable brioadened our perspectives, so that now we can see previously invisible phenomena (birth of stars, cannibal galxy chewing, logistic radiation of the Great Smash). Wide range radiation of invisible and visible wavelengths, through which we can now see our Universe is called *electromagnetic radiation (EM radiation).* That energy is composed of two components: electric and magnetic, which are invisible, namely which exist in the form of electric and magnetic fields. Strongest electric field implies also strongest magnetic field. There are also other kind of waves, such as sound and water waves, but actually they are vibrations of the fluids. (water and air), instead of vibrations of electric and magnetic fields.

2. Spectrum of EM – radiation

Long wavelengths (radio waves) have less energy than short wavelengths (x–rays). This is the difference in the energy quantity. Now we can understand why x-rays are more dangerous than radio waves and why they have stronger percussion power. Photon of radio waves has a milliard part of energy of the photon of x-rays. Therefore, if we want to send certain quantity of energy, we can send one photon of x-rays or milliard photons of radio waves. EM radiation streaming from the Sun is actually storm (followed by the hail) of photons. At that moment, x–rays are the largets pieces of hail, large as a ball, strong, but fortunately rare. It is also interesting that plants are adjusting in relation to the Sun position, naturally to receive as more flux as possible. Light is quite the same kind of radiation as radio, x-rays etc. It comes into small packages, whose enerегy depends on the wavelength and collection of many of those packages provide us with energy for photosynthesis, climate, solar cells

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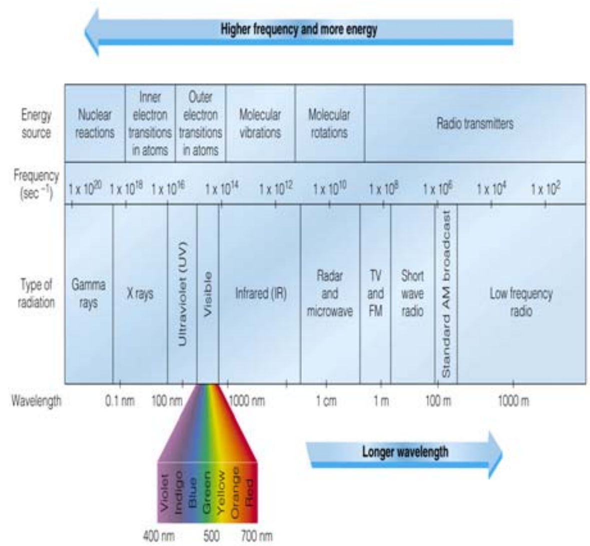
etc. Most of experiments with EM radiation deal with researches of different visible light wavelengths. Visible light is ranging from 400 nm (400 milliard part of a meter, adequate to violet light) up to 700 nm (red light).

Figure 1: Spectrum of electromagnetic waves



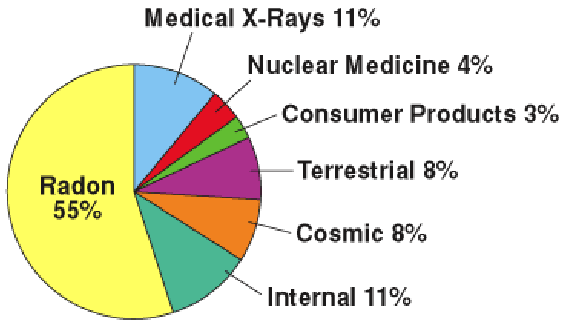
3. Ionizing radiation

Energy transfer between the system and environment over electromagnetic waves is called thermal radiation. With standard temperature, broadcasting waves correspond to infrared part of electromagnetic spectrum. Heat is transferred from the body into environment and the other way around. The power of thermal body radiation of its temperture (T) and surface (A) can be calcualted by *Stefan–Boltzman law on radiation:* $H_{zr} = e\sigma T^4 A$ *where e presents the emission, which for human skin is 0,98.* When calculating difference between energy received from environment by the body and energy broadcasted by the body, the resultant radiation power will be: $\Delta H_{zr} = e\sigma T_t^4 A - e\sigma T_0^4 A = e\sigma(T_t^4 - T_0^4)A$, where T_t *is body temperature and* T_0 *is environmental temperature.*

Materials which broadcast this kind of radiation are marked as *radioactive* and pass through the phase called radioactive decay. *Radiation* implies transfer of energy by electromagnetic waves, with no intevention of teh substance and in the distance. The rate of emission of electromagnetic waves (*c*), wavelength (λ) and frequency (ν) stnad in relation: $c = \lambda\nu$. Radiation has a binary nature: corpuscular and wavy. They are related to radiation origin.

Spectrum of EM waves is ranging from extremely high frequency and short wavelength to the waves of extremely low frequency (ν) and large wavelength (λ). In the course of decreasing frequency, the spectrum includes: gamma rays, strong and weak x–rays, ultraviolet rays (UV), luminous rays, infrared rays (IR), micro waves and radio waves. Nature of this kind of radiation is a corpuscular one, due to the fact that it is based on the particles – photons. This group includes cosmic, γ i *x*–rays, which are strongly penetrating. Longwave radiation appearing with the change of electrical potential (TV antenans and radio stations) also passes through materials.

Figure 2: Pie Chart of Ionizing Radiation



4. Radiation impact on health

The effects of ionizing and non-ionizing radiation can be expressed directly on the radiated person by means of somatic effects or indirectly, on offspring, by genetic effects. Low dose radiation increases cancer and leukaemia probability (late somatic effects) and genetic impairments. Risk of the radiation is determined by monitoring of the health of people radiated by high dose radiation. On considering preventive protection measures, factors such as speed and method of radiation and contamination of population, will be of immediate decisive importance for selection of the method, regularity, speed of protection and removal of effects. Above all it is necessary to take into consideration somatic impairments appeared with human being due to exposure to high dose of ionizing radiation. The term somatic hurt (somatic effect) is principally used in relation with clinically manifested effects, arising due to cell impairment after the exposure to irradiation. These effects may be manifested after a couple of hours or weeks, or after a couple of months or even after many years.

In case of a nuclear accident, high neutron flux and the increased temperature cause to happen melting of the protective layers and the release of physion products. A major part of solid radio nuclides are retained in the air filtration system, but on it saturation, the particles below 0,1 μm pass through and go in the atmosphere. Certain steams and gases easily go through the air filtration system and go loosely in the atmosphere. They are mainly gas and volatile products (bromine and iodine and their derivatives), inert gases (krypton and xenon), so as members of the family arising from beta – decay (^{35}Br, ^{36}Kp, ^{37}Rb, ^{38}Sr, ^{39}J, ^{53}I, ^{54}He, ^{55}Ce, ^{56}Ba, ^{57}La). Prior to the selection of the method and the kinetics of decontamination, it is necessary to examine each procedure in the limit cases including those with chemically active gas and those with chemically inert ones. Based on the results of examining this chemical pattern, we consider that all remaining gases will be placed within the limits got by examining this pattern with certain level of efficiency in preventing contamination of working and living environment.

Figure 3: Diagnosing patient using scanner

Subsequent effects of radiation exposure may be manifested by nephrosclerosis, cataract and tumor (with special attention to leukemia). In the same way, exposure to the lowest amounts of radiation may accelerate the process of ageing. From the above mentioned, it is clear that the risk from small doses of radiation is estimated according to monitoring of health of people radiated with high doses, i.e. doses causing visible effects (acute, from 4.5 Sv, all radiated people will be seriously sick and approximately a half of them will die). That amount of dose represents medium lethal dose. By increasing the radiation dose, signs of weakness and death are appearing more rapidly. Innate differences in sensibility and resistance between individuals explain diverse consequences that may occur from the same dose.

Figure 4: Doses from Typical Radiation Sources in USA

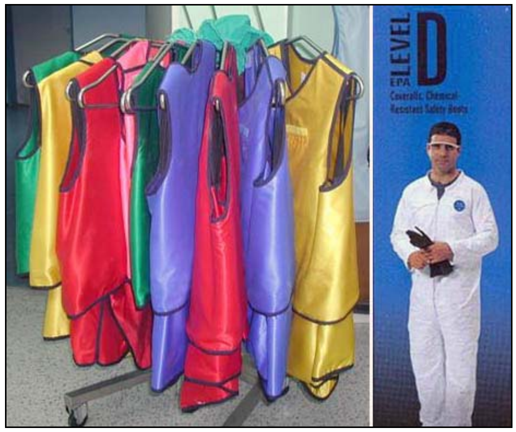
Background[9,23]	cGy/yr
AL, LA, MS	0.22
CO, ID, NM	0.72
^{40}K adult human	0.026
UK Radiologists[10]	0.05-5
Technological[23]	
nuclear power	0.0003
nuclear fallout	0.004
nuclear devices[a]	0.005
Medical Imaging	
	cGy
mammograms[18,19]	0.4
chest X-ray[b]	0.025
dental, full-mouth[b]	0.017
CT scan, head[b]	2
CT scan, body[b]	6
thyroid scan[19]	
^{131}I	5-10
^{123}I	3-5
^{99}Tc	1

[a]smoke alarms, pacemakers, gauges
[b]see text

5. Radiological protection in diagnostics

The quality of radiation protection has different forms depending on type of radiation source and human activities, which lead to exposure to ionizing radiation. Reduction of unnecessary radiation is of special importance and it is achieved by application of basic principles of radiation protection (justification of practice, optimization of protection, limitation of individual doses and risks). Ionizing radiation in medicine are undoubtedly an important diagnostics and therapeutic treatment. In spite of development of alternative methods, diagnostic methods that use X-radiation remained almost unaltered. Owing to their specificities, medical exposure and protection of patients in x-ray diagnostics are treated separately from exposure of professionally exposed individuals. Optimization of the protection in radiology actually means an effort to find the compromise between quality information provided by diagnostics procedure and quality effects of therapy procedure on one side and dose of radiation received by patients on the other. Professional and scientific institutions, dealing with issue of radiation protection in medicine, as a mean of optimization suggest the introduction of limit values that separate good from bad radiology practice. The need for introduction of patient dosimetry is formulated by the Law on Protection Ionizing Radiation (Official Gazette of the Federal Republic of Yugoslavia No.46/96), Guidelines on exposure limits to ionizing radiation and Guidelines on application of ionizing radiation source method in medicine (Official Gazette of the Federal Republic of Yugoslavia No. 32/98). Doses are determined by continuous improvement of techniques for production, detection and control of x-ray radiation, including the development of alternative diagnostic methods and initiatives for quality control and patient protection.

Figure 5: Protective clothes and level of protection for diagnostics



Introduction of digital techniques led to significant changes in clinical practice. Considering the possibility for reduction of doses, ICRP recommends the use of referent level of doses (RDL) in diagnostic radiology, as a result of optimization of protection from radiation and basis for application of ALARA principle. Reaching and maintaining a good clinical practice within diagnostic radiology consists of frequency and number of checkups control and level of patient doses. When it comes to justification of practice, all alternative diagnostic methods should be considered. Special attention should be paid to radiology practice justification for pediatric patients, who have a greater long-term risk due to ionizing radiation exposure.

Table 1: Risks connected to R-radiation exposure

Estimated risk from R – diagnostics	Innate risk from malign diseases		
Lungs	1/1.000.000	Lung carcinoma	1 / 16
Lower GIT	1 / 3.000	Large intestine carcinoma	1 / 44
Mammography	1 / 100 000	Breast carcinoma	1 / 21

The program of patient dosimetry, according to established protocol, is conducted at least once in three years or after each intervention with x-ray machine or after modification of procedure, which may influence the patient's dose. In line with Euroatom Regulation 43/97, for DRL within diagnostic radiology it is necessary to take those values that ensure identification of procedure resulting unnecessarily in high dose for patients. Apart from the most frequent checkups, due attention deserve checkups with high individual doses. On national level, competent authorities must provide information flow and adequate literature. The most frequent causes of unjustifiably high patient doses while taking X-rays, lie in lack of technical knowledge. Aiming at immediate display of the dose, it is introduce the kerma in the air at the surface of patient's skin, at defined reference level. There are four types of measuring used in diagnostic radiology: dose or kerma on the surface of the patient's skin, estimation of dose for organs, estimation of dose within the detector functioning as resulted blackening of the film or outgoing signal and measuring of weakening behind the patient but in front of the receiver of picture. Each manifested referent level has to be connected to date of determination; the source of information must be stated, as well as time of the next series of measuring. DRL represents only the first step; therefore the concept of reachable doses must be adopted. Referent dose values for different age of pediatric patients are derived based on available dosiometric data on European level. Searching for reasons for exceeding referent levels, the quality of X-ray findings has to be taken into account, based on contrast and optical density measuring. Formation and exploitation of the database should be the basis within the process of optimization. Producer of equipment must be informed about consequences of requirements imposed on him regarding the dose and price of equipment. Criteria for quality management within protection from ionizing radiation used in diagnostic radiology was given by European Commission: European Guidelines on Quality Criteria for Diagnostic Radiographic Images, EUR, 16260.

6. Conclusion

Electromagnetic radiation in working and living environment represents waves of energy with electric and magnetic features, originated by vibration and acceleration of electric charge. The spectrum of electromagnetic waves is extending from waves of extremely high frequency and short wave length to waves of extremely low frequency and long wavelength. Current knowledge on the impact of non-ionizing and ionizing radiation and, according to that, rules for protection, are built on a very contradictory assumption, that the probability of appearance of harmful consequences is linearly proportional to radiation dose. The risk from radiation is determined by monitoring health of people radiated by higher radiation doses, which may be expressed to greater extent in the conditions of usage of N-weapons, accidents or terrorism with the increased radiological contamination. In the center of out interest there are undoubtedly the problems of the protection against ionizing and non-ionizing radiation, defence and safety from nuclear accidents and terrorism. Preventive medicine has its important place in early detection of the diseases of ionizing radiation, and the related causes and sources.

Optimalization of radiological protection in diagnostic radiology means actually an effort to find the compromise between diagnostic information obtained by an X-ray finding and dose received by the patient. Adhering to all the required diagnostic requests, dose for the patient should be as low as possible. Reference doses in diagnostic radiology are means for checking, aiming at identification of health institutions disposing of unacceptable dosimetric information. Establishment of reference doses on national level implies previous necessary education and training of the staff within the area of radiological protection. Quality transfer of information within the area of protection must be ensured, so to apply suitable measures and activities. Relevant publicatons should be made available and presented on national and international level. Competent institutions and scientific staff members are obliged to provide information flow and approrpiate literature and transfer of knowledge in these issues. Staff education and adequate equipment from the protection from radiation must be harmonized with adopted terminology, which is of key importance for distribution of relevant data. The goal of this work is to reduce the risk, by using knowledge and existing experiences and by applying theory of games, while multi-criteria decision-making in conflict situation as well as making decisions in the peace practice, especially on establishing patient's diagnosis. It is quite ceratin that also here there is a «response» to nuclear (radiologic) danger, ranging from classical safety measures to activation of the competent specialized institutions, specially equipped for taking protective measures from ionizing radiation. Establishment of such a system should be based on operational researches, while the system should respond to tasks, factors, structure of organization, management and IT support, so as to design basic parameters, procedures and reactions in the system of quality protection from ionizing radiation and nuclear safety.

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