Review

The importance of public health in radiology and radiation protection

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Introduction

In this time exist many risk factors, that endanger human health: biological, chemical, physical, psychosocial, economic, and other. Physical factors include ionizing radiation, ultraviolet radiation, infrared radiation,microwaves and radio waves, noise, vibration as well.

The ionizing radiation is very important risk factor. But using the ionizing radiation has many benefits in medicine, specifically in the means of prevention, diagnostics, and therapy of various diseases. The bases of some diagnostic methods are the imaging technique that produces the ionizing radiation. On the contrary, other diagnostic methods use for visualization radioactive contrast dye that is being applied to the patient during the examination. Thanks to the advancement in radiology, the diagnostics of many diseases that are the cause of morbidity and mortality of a population, has become easier. Also, many of the therapeutic techniques are based on the methods that use the ionizing radiation, such as radiotherapy of oncological diseases.

It is well known that role of the public health is to minimize the impact of risk factors and, conversely, to promote the impact of protective factors. Ionizing radiation is a factor with indispensable benefits, but with its reckless use and irrational exposures, it can lead to serious health problems. The aim of all radiological methods as well as the public health is to lower the mortality and morbidity of individual diseases and thus elongate a patient's life. The public health and the radiation protection share many of the same aims. the main aim is patient-oriented, and it is about minimizing negative biological effects of the ionizing radiation in medical examinations. The second aim is workers-oriented, who work with the source of the ionizing radiation. This means, that it is a cooperation between radiation protection, public health and occupational health.

Unfortunately, one of the problems is that presently, the radiation safety is not emphasized in public health enough. On the contrary, it is often undervalued, even negatively received. Yet, it is a major problem, because the public health plays an important role in radiology and radiation protection.

To the potential applications of public health in radiology can be included identification the most appropriate medical imaging for prevention, diagnostic and treatment diseases. Clinical effectiveness, clinical or radiation epidemiology, biostatistics, research, quality improvement or quality improvement evaluation, overall management of patient and radiology strategies are other ways to involve public health in radiology.

The next importance of public health in radiation protection also lies in the ability to remind about the importance of radiation safety or monitor and analyse the patients' radiation dose. It can also help with optimizing individual imaging methods, minimizing the collective dose, as well as minimizing the risk coming from patient's exposition to the ionizing radiation. It should also inform the medical workers, how to shield themselves better from the exposition; help with minimizing the cumulative dose and radiation risk of medical personnel, who works with radiation source. Finally, the public health can educate the medical workers about radiation safety for example, as well as gen up them with recent trends regarding radiation protection in medicine and new legislation, *etc*.

At present the public health is oriented at biological, chemical or lifestyle risk factors which cause most often acute or chronical diseases. When public health is oriented at physical factors, they are standard physical factors of as noise, vibration, lighting etc. But the ionizing radiation belongs to the basic physical factors that can be measured and when the exposures are excessive, they influence the health negatively.

This article stresses the importance of one from more physical factors, that causes exposure of patients as well as medical worker. Because the radiation plays very significant role in our life and our health, we cannot forget it that exposure of ionizing radiation is not only problem of radiology or radiation protection. On the contrary, it is problem of radiation protection and public health because the public health has a multidisciplinary character.

Role of public health in radiology and radiation protection

Public health is defined as "the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society".[1] From the definition implies, public health should be involved in all areas that may have any impact on human health. It can be an effort to minimize the exposure of risk factor – ionizing radiation or to deal with quality in health care – in radiolo-

Significance for public health

The aim of all radiological methods as well as the public health is to lower the mortality and morbidity of individual diseases and thus elongate a patient's life. The public health and the Radiation Protection share many of the same aims. The main aim is patient-oriented, and it is about minimizing negative biological effects of the ionizing radiation in medical examinations. The second aim is workers-oriented, who work with the source of the ionizing radiation. This means, that it is a cooperation between radiation protection, public health and occupational health. Public health can help to minimize the exposure of risk factor – ionizing radiation or to deal with quality in health care – in radiology. The can to cooperate in obtaining the necessary information for evidence-based medicine that is an integral part of all medical disciplines, including radiology and radiobiology.

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We cannot forget about epidemiological studies and observations playing an important role of medicine. They are the only way to detect the influence of various factors, as well as ionizing radiation, to the human biological system. The multidisciplinary character of public health, the knowledge of concepts related to epidemiology also helps to correctly interpret research results and to prevent the formation of incorrect research conclusions.

Among other things, currently, screening programs are an integral part of healthcare and some of them (for example mammography screening) are based on imaging methods that use X-ray. While clinical radiology deals with imaging methods for the diagnosis and treatment of diseases, public health radiology imaging deals with radiological imaging methods used in screening.[2] The public health experience and its collaboration with experts in radiology and radiation safety can help assess the risk and benefits of the imaging methods. It can compare the radiation exposure of individual imaging methods or actively monitor compliance with diagnostic reference levels (DRLs) of patients or dose limits of medical worker as well.

Based on the European Directive 2013/59/Euratom, it is required that all of the member states of the European Union ensure justification and optimisation of radiological methods and archive the information about the exposition of patients for the purpose of analysis and assurance of quality. Loose discusses these requirements in his work *Radiation dose management systems—requirements and recommendations for users from the ESR EuroSafe Imaging initiative.*[3] In the Slovak Republic, there requirements are defined by the specific law "101/2018 Statute", which defines details about ensuring radiation safety while executing medical radiation.

Even though all the radiology working sites archive the information about the level of radiation burden of patients, continual evaluation of the radiation burden of patients is a very important aspect. Because the radiological working-sites focus on offering quality health care to the patients, they do not have enough time nor experience with radiological epidemiological and statistical processing of available data. However, modern devices and software allow automatic transferring of data, or control over the expositions with DRLs, nevertheless, it is important to process data right towards the radiation epidemiologists and consequently consult the results with the medical physics expert or medical radiological, which are responsible for correct adjustment of the devices, optimizing the examinations and applying the "as low as reasonably achievable" (ALARA) principle in practice. Here, it is possible to use the multidisciplinary approach of public health, which is capable of training radiation epidemiologists. Thanks to the multidisciplinary approach, it is possible to accomplish a higher level in radiology, because the statistical evaluation of the acquired dosimetry data is the basis for analysing, optimizing and clinical audit.[3] Seeing that in the modern time, the demand for the radiation imaging techniques as well as using the ionizing radiation in medicine rises, the issue of radiation safety and the multidisciplinary approach has not yet been as desirable as it appears to be nowadays.

Within the frame of the European radiological society campaign - *Eurosafe Imaging*, the *Dose Management* work group has been created. Its aim was to ensure the implementation of the European recommendations on the implementation of management systems in clinical practice. One of the main activities of the European radiological society is to support the system of controlling and assessing the local, national, and European DRLs.[3] Presently, only the DRLs of the national level are defined in the Slovak Republic, and they are anchored in the decree of the Ministry of Health of the Slovak Republic, that was updated in 2018 *Measure No. S02933-2018-OL,* dated March 19th 2018, which constitutes the diagnostic reference levels of medical radiation. The local DRLs are frequently absent and also, in many specialized radiological examinations, the DRLs are not defined.

Beside the radiation safety that is focused on the patients, we should not forget about the occupational exposure. For example, lowering the equivalent dose limit for the lens of the eye for occupational exposure. Thanks to the epidemiological studies such as the ORAMED research, we came to a conclusion that the lens of the eye is far more sensitive than we had previously assumed, which was the base for updating the equivalent dose limit.[4,5]

Updating the DRLs, limits, legislature, guidelines, and recommendations requires conducting out quality epidemiological research. However, this can only be executed if we abide the multidisciplinary approach and collaborate with multiple disciplines. The proof of this is the novelization of the European Directive 2013/59/Euratom, which was established in collaboration with many specialists and their years of experience and research.[4,6] The most important changes that occur in the guidelines were written by Torresin *et al*. in their *Practical recommendations for the application of DE 59/2013.*[6]

Next problem can be radiation safety knowledge of medical workers. Due to the enormous increase in the use of sources ionizing radiation in medicine and rapid development, there may be a disproportionate acquisition of radiation safety knowledge of healthcare workers. It is essential that the education and training of healthcare workers working with source of ionizing radiation keep pace with new trends and knowledge of radiation protection.

Based on the above information, it follows that public health can play an important role in radiation protection and in radiology, as well. Also, it is important implementation radiation epidemiology in practice and develop this special field of epidemiology in public health.

Role of public health in radiation safety of the patients

Why are exposures of ionizing radiation patient's global and public health problem? The answer to this question is very easy. In modern medicine, radiology plays an important role. Even though the benefits of medical exposures prevail over the radiation risks, there are concerns connected to the unwanted biological effects of ionizing radiation.[7]

Based on the knowledge about radiation, we know, exposure of cells to any form of ionizing radiation is connected to a potential risk of biological cell damage. The main effect of exposure is molecule ionization and actions that follow, which cause irretrievable cell damage. The target molecule of ionizing radiation is the DNA molecule, but it effects also other molecules such as proteins and lipids.[8,9] The mechanisms of ionizing radiation are very complicated and consist of physical, physical-chemical, chemical and biological processes that cause the final radiobiological effect.[10]

Based on the ICRP recommendations, the negative biological effect of ionizing radiation exposure can be divided in two general categories. The first one contains the biological effects caused by the exposition to high doses, so called deterministic effects. These follow immediately after the exposition when a certain threshold of dose is crossed. The second category contains the biological effects that are caused by low doses of ionizing radiation, so called

stochastic effects. For stochastic effects do not exist threshold level under which biological effect do not occur. These effects do not cause immediate clinical manifestations and they are unpredictable. They mainly damage the cell itself, and the biological effects can be seen after several years go by.[11]

The radiation used in medicine, represents the biggest part of the radiation that comes from artificial resources. The reason is an increasing demand for X-Ray with an accent on the computed tomography (CT) and the multidetector computed tomography, which represents 50% of the medical' expositions.[12] The yearly rate of carried out X-Ray examinations is more than 3600 million (of which approximately 10% represent the children´s expositions), 37 million examinations in nuclear medicine and 7.5 million procedures of radiotherapy.[13] It is assumed, that this number will increase due to population aging that is affected by multiple diseases and injuries. Simultaneously, ionizing radiation is being increasingly used in diagnostics in children. Child population is more sensitive to the oncogenic effects of ionizing radiation. This leads to higher risk of acute leukaemia and solid cancers. In comparable exposition parameters, the effective doses and their risks are 50% higher in children than in adults. This risk is higher especially because of the smaller bodies of children and the number of proliferating cells that are sensible to radiation exposure. Thanks to the longer living, the children have a higher risk of cancer caused by exposure of ionizing radiation than the adults.[14,15]

Many studies assumed that the wider use of CT can cause small, but appreciable abundance of cancer risk. The problem occurs with the repeating radiation examinations, whereas the patient cumulative dose is increased and so the risk of biological damage also increases. The increase of the cumulative dose of patients, radiological workers, and the population lead to an effort to systemically lower the radiation dose by developing the tools for its decrease and optimizing sources of ionizing radiation. Including the audits that focus on the betterment of radiation safety among the medical workers.[7]

Along with the increasing cumulative dose of population, the cancer risk also increases during life. The European Commission has dealt with this issue in 1997 and it has published several recommendations. There is possible to integrate the competencies of Public Health in the process of radiation safety. The public health worker can realize campaign and thus to remind the indicating doctors of the fact, that indicating X-rays or CT is not the only option in diagnostics and it should not become the first choice. Since a high amount of indicated and carried out CT examinations often is not the result of their rational use, it is important to remind of the principle of justification.

Due to irrational use of CT, and in many cases groundless indication of CT by the doctors, some countries have created clinical guidelines to support rational usage of CT. In the USA, The National Institute for Health and Clinical Excellence has published guidelines about proper usage of CT and magnetic resonance imaging. With the aim to lower the number of groundless medical expositions, the campaign with name *Choosing Wisely* has been launched in Canada and the USA.[16] Similarly, the FDA had started a campaign with the same aim, which was mentioned in the *National Council on Radiation Protection and Measurements Report NO.160*. Some studies show, that a third of all CT examinations are carried out unnecessarily. Among these are the cases when X-ray or CT examinations were indicated without adequate reasoning, improperly, controversially, or repeatedly due to insufficient communication among the doctors.[17] A similar campaign (*3A–Audit, Appropriateness and awareness*), was launched by the IAEA. Its aim was to improve the principles of justification in radiological examinations which is an effective tool for primary cancer prevention.[18,19] With the aim to ensure and support the radiation safety, the IAEA created action plans, for example the *International Action Plan for the Radiological Protection of Patients* or the *International Action Plan on Occupational Radiation Protection*. In the Slovak Republic, this issue is dealt by the Standard diagnostic procedures that are being prepared consecutively and they regulate the indicating criteria as well as the terms of radiological examinations. For example, *Standard procedure for executing the medical X-ray examinations – Computed tomography*, *Standard procedure for executing the medical X-ray examinations – Skiagraphy and fluoroscopy*, *Standard procedure for executing the medical X-ray examinations – standard operating process for diagnostic mammography*, *Standard procedure for executing the medical X-ray examinations for prophylaxis – screening mammography*, *Standard procedure for executing the medical examinations in nuclear medicine*.

But setting standards and norms is not enough in this area. It is very important that the public health professional or radiation protection worker has an active attitude to the issue, to constantly monitor the radiation exposure of patients and to support the rational use of radiation imaging methods.

Role of public health in radiation safety of the medical workers

Another risk group except the patients are the medical workers who work with the ionizing radiation. They are exposed to the ionizing radiation on daily basis because of various radio-diagnostic and therapeutic interventions. These expositions are connected to various acute or late effects.[20-24] With the aim to prevent the deterministic effects and minimizing the stochastic effects, the IRPA has created several recommendations and set dose limits that should not be exceeded. In the legislation of the Slovak Republic, these norms are defined in the Law No. 87/2018 about the radiation safety and changes and completing of some laws.

Presently, with the increase in the number of examinations using the radiation, it is important for the medical workers to know the ways how they can shield themselves effectively.[25-27] One of the components that can contribute to the correct way of shielding the workers is a measure of knowledge about the radiation safety, which has a big influence on the correct actions and performance in the field of radiation safety. Within this context, Behzadmehr conducted a systematic review. Its aim was to map the knowledge, access, and experience of medical workers in the field of radiation protection. Specifically, 41 scientific studies were chosen based on defined criteria that evaluate the adequacy of the research. The results of the research gather valuable information and scientific proofs that education of medical workers is the most important method of applying the fundamentals of radiation safety. From the analysed studies, 13 studies recommend incorporating the subject of radiation safety into the curriculum, 12 studies recommend implementing completing the training and direct acquiring of practical knowledge in the hospital, 11 studies recommend providing programmes of further education and 8 studies recommend providing adequate safety tools.[28]

Even though the medical imaging tools advanced and ionizing radiation is more commonly used in medicine, the knowledge about radiobiology, radiation safety and optimizing criteria has lessened. Knowledge has a direct impact on implementing the safety measures of radiation safety and the focus on this issue is necessary.[29] Professional preparation and education in the field of radiation safety is considered one of the basic components of opti-

mizing programmes focused on medical exposure. Many international organizations, such as ICRP, WHO, IAEA, together with the EC emphasize the importance of education and professional preparation of medical workers, which is necessary to lower the radiation dose that comes from medical exposure and to lower the risk associated with the exposure.[14]

One of the most important challenges that the WHO deals with contains professional preparation, provide guidelines, technical messages and keeping up with the principles of radiation safety, which are all mentioned in the document *Global Initiative on Radiation Safety in Healthcare Settings*. The WHO assumes that a great investment is necessary for minimizing the risks and insuring a safe and effective healthcare, so that the medical workers can gain the necessary knowledge, views, and professional experiences. The medical workers often lack the necessary knowledge of the risks associated with the exposure to ionizing radiation. This can be explained by the fact that the medical workers often have negative or neutral views about radiation safety, which leads to lower ability of applying knowledge about radiation protection in practice. The importance of radiation safety in medicine and the measures for supporting radiation protection were defined in 10 points which are part of the document *Bonn call for action.*[30,31]

During the last decade, many studies in different countries have been conducted to analyse the knowledge of medical workers about the issue of radiation safety.[32-38] Many of them showed unsatisfying results. For example, there was realized an Italian study that used the questionnaire method. 780 radiologists completed the questionnaire. 12% of radiologist confirmed that they regularly attend trainings that focus on this issue and 56% of radiologist rarely. On the contrary 32% of radiologist have never attended course about radiation protection.

Even though 90% of the respondents of this study marked that they have enough knowledge about radiation safety, the average success rate of the questionnaire was only 53%.[12] In another study, the average answer score of the medical workers was 50%, of whom 48% answered more than half of the questions. Only 23% of the respondents have been aware about the radiation dose related to the X-Ray examination, 50-70% of them undervalued radiation exposure and 50-75% of them undervalued the potential radiation risk of dying of secondary induced cancers.[39] The questions concerning the radio-sensitivity of tissues and organs, as well as defining the imaging methods that use or do not use ionizing radiation (for example magnetic resonance imaging, ultrasonography, CT, mammography) also showed surprising results.[7,12,40,41]

An interesting study in this field is the Hagi's study, which focused on evaluating the knowledge of medical students in Saudi Arabia. The students attended a didactic presentation about radiation protection. They completed the same questionnaire before and after the presentation. In the questionnaire before the presentation, only 17% of students scored more than 60%. When comparing their knowledge before and after the presentation, there was an improvement in their knowledge. The average score before the presentation had been 47% and after the presentation, the score improved by 31%, therefore the average score was 78% (p=0.01). The results of the study confirmed that as little as one presentation can help improve the knowledge about general principles considering ionizing radiation and radiation safety.[40] It is necessary to continue this trend and to bring forward the issue of radiation safety.

Although we compare the results of studies that were performed on different samples with different occupational and age range (radiologists, emergency physicians medicine, students of radiology, students of medicine), we can see that the topic of education of health professionals cannot be underestimated. As mentioned above, the knowledge of some medical workers about radiation protection and ionizing radiation are in some cases insufficient. It has been the result of several studies.[7,12,29,32,40,42-44] Because a medical worker plays a crucial role in radiation safety, it is very unsettling that these people do not have enough knowledge in the field of radiation safety many times. It follows that they do not know in many cases how to adequately implement the basic principles of radiation protection into their medical practice. Based on that, it is necessary to say that this is a serious problem of public health, which should be the Public Health dealt with. It is of utmost importance, that the medical workers have enough knowledge about ionizing radiation and the risks that are a big part of the exposition. Considering radiation safety, the medical workers should regularly attend courses lead by a qualified person that can offer the workers new information considering the legislation and other guidelines.

Underestimation of significance of education in the field of radiation safety of the medical workers can have dangerous effects, which can lead to higher number of unnecessary X-ray examinations, higher expositions of patients, wrong usage of safety tools, insufficient covering of radiosensitive organs and many other substantial consequences.

Conclusions

The radiobiological imaging methods offer valuable information in diagnostics and therapy. However, if they're used irrationally or if the safety measures integrated into the principles of radiation protection are not respected, the exposition to the ionizing radiation can lead to higher number of health risks for the patients as well as medical workers.

The specific aim of the study was to point out the importance one physical factor from more physical factors, which play very important role in medicine as well in public health. This importance can we see in the fact that ionizing radiation affects patients as well as healthcare professionals themselves. In order minimize the negative effects of ionizing radiation and increased its benefit, every healthcare professional must have adequate knowledge of ionizing radiation. Because the ionizing radiation is significance physical factor, we cannot forget the field of public healthcare system, who's main aim is safety, support, and development of the population's health. These are also aiming of the radiation safety. It is necessary to emphasize, that safe and effective usage of the ionizing radiation in medicine is one of the basic components of Good Medical Practice. To be able to prevent unwanted biological effects of radiation in the human body, realize epidemiology studies, regular education of the medical workers, as well as informing them about the effects and the mechanisms of this radiation on human cells is necessary. Hereby, it is inevitable to know the sources of the ionizing radiation and the ways for lowering the exposure to the lowest possible level, while keeping the maximum of its benefits.

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