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ORIGINAL ARTICLE

THE ASSESSMENT OF THE IONIZING RADIATION DOSE RECEIVED BY PATIENTS DURING SOME DIAGNOSTIC X-RAY EXAMINATIONS CARRIED OUT ON THE BASIS OF THE WORKING PROCEDURES IN THE HEALTH CARE ENTITIES[1]

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ABSTRACT

Background. X-ray examination is a popular and universally used injury and disease diagnostic method. A distinctive X ray examination feature is that it can be done quickly which is extremely important in case of the need for rapid diagnosis of patients in life threatening condition. Another advantage of the X-ray examinations is also relatively low cost of carry. However, X-ray examination involve adverse health effects. During the examination the patient is subjected to ionizing radiation that might have impact on his health.

Objective. The aim of this study has been to determine and assess the size of the entrance surface doses (ESD) received by patients during selected X-ray examinations performed on the basis of the medical working procedures available in healthcare entities in Masovian Voivodeship in Poland.

Materials and Method. The examinations were conducted for 71 X-ray units located in the Masovian Voivodeship. Measurements of doses received by the patients were based on our own validated test methods.

Results. It was found that the range applied to the high voltage in healthcare entities does not always coincide with the values specified in the standard procedures. It was found in the skull projection radiography AP and LAT that the recorded values were from range 60 to 82 kV (the average value of 74 kV) while in accordance with a standard procedure they should be in the range from 65 to 75 kV. Only in case of cervical spine radiography in the AP projection, the LAT exposure conditions were matching with the standard obligatory procedures in Poland. The consequence of selecting exposure conditions are significant differences in the size of the doses the patient receive during the same medical procedures. The greatest range of ESD doses was found during radiography of the thoracic spine in the projection AP and LAT. The projection LAT measured values were in the range of 523 to 10550 μGy (average value 2175 μGy).

Conclusions. It is necessary to update immediately the standard procedures and to develop detailed guidelines for the preparation of working procedures in X-ray rooms.

Key words: *radiological procedures, entrance surface dose (ESD), X-ray examinations, X-ray exposure*

STRESZCZENIE

Wprowadzenie. Badania rentgenowskie są powszechnie stosowaną metodą diagnozowania urazów i schorzeń występujących u pacjentów. Największą zaletą tych badań jest szybkość ich wykonania, co jest niezwykle istotne w przypadku konieczności postawienia szybkiej diagnozy medycznej u pacjentów w ciężkim stanie zagrażającym ich życiu. Badania rentgenowskie niosą jednakże ze sobą także negatywne skutki zdrowotne. W trakcie ich przeprowadzania pacjent poddany jest działaniu promieniowania jonizującego, które nie jest obojętne dla zdrowia.

Cel. Celem badań było oszacowanie wielkości wejściowej dawki powierzchniowej (ESD) jaką otrzymują pacjenci podczas wybranych badań rentgenowskich przeprowadzonych w oparciu o procedury robocze obowiązujące w placówkach ochrony zdrowia na terenie województwa mazowieckiego.

Materiał i metody. Zbadano 71 aparatów rentgenowskich wykorzystywanych w placówkach ochrony zdrowia na terenie województwa mazowieckiego. Pomiary dawek otrzymywanych przez pacjentów podczas badań rentgenowskich przeprowadzono własnymi zwalidowanymi metodami badawczymi.

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Wyniki. Stwierdzono, iż zakres wartości wysokiego napięcia dobieranego przez personel medyczny na aparatach rentgenowskich w placówkach ochrony zdrowia nie zawsze pokrywa się z wartościami określonymi w procedurach wzorcowych. Stwierdzono, iż w radiografii czaszki w projekcji AP i LAT wartość wysokiego napięcia była od 60 do 82 kV (wartość średnia 74 kV), zaś zgodnie z procedurą wzorcową powinny mieścić się w zakresie od 65 do 75 kV. Najlepszą zgodność pomiędzy wartościami wysokiego napięcia stosowanymi w pracowniach rtg a tymi określonymi w procedurach wzorcowych obowiązujących w Polsce stwierdzono w przypadku radiografii kręgosłupa szyjnego. Konsekwencją tak dobieranych warunków ekspozycji są znaczące różnice w wielkości dawek promieniowania otrzymywanych przez pacjentów dla tych samych procedur medycznych. Największą rozpiętość dawek ESD stwierdzono w trakcie radiografii kręgosłupa piersiowego w projekcji AP oraz LAT. W projekcji LAT zmierzone wartości były w przedziale od 523 do 10550 μGy (wartość średnia 2175 μGy).
Wnioski. Niezbędne jest jak najszybsze uaktualnienie procedur wzorcowych oraz opracowanie szczegółowych wytycznych dotyczących przygotowywania procedur roboczych w pracowniach rentgenowskich.

Słowa kluczowe: *procedury radiologiczne, wejściowa dawka powierzchniowa (ESD), badania rentgenowskie, ekspozycja rentgenowska*

INTRODUCTION

X-ray examination is a popular and universally used injury and disease diagnostic method. They are conducted in order to assess the magnitude of post-traumatic changes, the suspected fractures, dislocations, but also the diagnosis of inflammatory, degenerative and congenital malformations. A distinctive X ray examination feature is that it can be done quickly which is extremely important in case of the need for rapid diagnosis of patients in life threatening condition. Another advantage of the X-ray examinations is also relatively low cost of carry. On this account you can see a continuous increase in the number of X-ray examinations performed [1]. However, X ray examination involve adverse health effects. During the examination the patient is subjected to ionizing radiation. The size of exposure depends on several factors, ie. the condition of the X-ray tube in which the test is performed, but also the method of examination by X-ray technician. The X ray technician after analysis of the referral, which is determined by the type of examination, selects the appropriate exposure conditions and prepares the patient. These activities are of great importance from the point of view of obtaining the correct X-ray image on the basis of which the doctor makes medical diagnosis. It also affect the dose of radiation received by patients. Considering the above, standard radiological procedures has been developed [7, 8], under which healthcare entities prepare their own operating procedures for performing X-ray examinations. Reference Procedures should therefore standardize the method of performing X-ray examinations in all medical centers using ionizing radiation for medical purposes. They impose the proper way of performing the examination by determining the exposure conditions, how to prepare the patient for testing, but also to specify the principles of radiation protection of the patient.

The aim of this study has been to determine the size of the input surface doses (ESD) received by patients during certain X-ray examinations performed on the basis of the working procedures available in health care entities in Masovian Voivodeship in Poland.

MATERIAL AND METHODS

At the outset of the study it was necessary to nominate the number of X ray units and healthcare entities at which measurements should be performed. For this purpose the results of previously conducted studies were used [2, 3, 4]. On this basis, it was found that the measurements should be performed for at least 63 X-ray units. When choosing a health care entities the location (city of Warsaw and other cities of the voivodeship) and the type of entity (hospitals, clinics, private medical centers) was taken into consideration. In each selected X-ray room the availability of working procedures for medical staff and measurements of the entrance surface dose value was verified.

For the measurement of the entrance surface dose value (ESD) Unfors RaySafe Xi was used. The dose detector was placed on the body phantom. Used phantom was made of PMMA (polymethyl methacrylate). The backscatter factor was also taken into account. In each of the selected X-ray room the X-ray technician was asked to perform a routine examination for an adult patient following their own working procedures. Each time the X-ray technician's task was to select the exposure conditions such as high voltage (kV), the load current-time (mAs) and the distance between the focus X-ray tube and a body phantom. Entrance surface dose was measured for the most commonly performed X-ray procedures [1] including radiography: skull, chest PA, cervical spine AP and LAT, thoracic spine AP and LAT, spine lumbosacral AP and LAT, pelvis AP elbow AP and LAT. Selected exposure conditions were recorded.

RESULTS

During the study 782 entrance surface doses were measured for 71 X-ray units. The value of high voltage (kV) and the load current-time (mAs) for each exposure was also collected. The results are shown in Table 1.

The results obtained in this study indicate that the range of high voltage in the X-ray examinations in the Masovian Voivodeship does not coincide fully with the values specified in the standard procedures approved by the Minister of Health in Poland. A good example might skull radiography in the projection AP and LAT for which the values were recorded in the range from 60 to 82 kV (average 74 kV). According to the procedure a model values should be in the range from 65 to 75 kV. Only in case of cervical spine radiography in the AP projection, the LAT exposure conditions were matching the model. The recorded values were in the range from 64 to 79 kV (average 70 kV) while the recommended standard exposure condition should be 65 - 85 kV. The attention should also be paid to the radiographs of the elbow joint projection AP, LAT. According to the standard procedure the examination should be carried out for the voltage of 65 kV (AP projection) and 70 kV (projection LAT). The exposure conditions used in X-ray rooms were not matching only for the average value (64 kV for the AP projection and 71 kV for projection LAT), while the range of selected conditions was much higher. In the case of the projection AP values were 60 to 70 kV, and the projection LAT from 60 to 75 kV.

Table 1. Exposure terms and ESD received by adult patients during conventional radiography X-ray examinations

Radiography	Range of the high voltage values according to the model procedure [kV]	Range of values applied high voltage in X-ray room [kV]		ESD for one projection [μGy]		ESD for the whole study [μGy]		Reference level [mGy]
	Range	Range	Mean	Range	Mean	Range	Mean	
Skull X-Ray, AP, LAT projection	65 – 75	60 – 82	74	AP: 326 – 2840 LAT: 248 – 1650	968 781	623 – 4251	1588	AP: 5 LAT: 3
Chest X-Ray, PA projection	117 – 125	102 - 125	118	224 – 1426	418	224 – 1426	418	7
Cervical spine radiography, AP, LAT projection	65 – 85	64 – 79	70	AP: 162 – 1018 LAT: 148 – 858	593 431	349 – 1621	962	-
Thoracic spine radiography, AP, LAT projection	75 – 85	67 – 96	81	AP: 418 – 5170 LAT: 523 – 10550	1492 2175	1007 – 12997	3308	AP: 7 LAT: 12
Lumbar spine radiography, AP, LAT projection	75 – 95	70 – 96	85	AP: 629 – 7109 LAT: 1180 – 23730	2122 6939	2014 – 27102	9512	AP: 10 LAT: 30
Radiography of the pelvis	75 – 90	70 – 85	77	328 – 4909	1593	328 – 4909	1593	10
Elbow radiography, AP, LAT projection	AP: 65 LAT: 70	AP: 60 – 70 LAT: 60 – 75	64 71	AP: 78 – 198 LAT: 98 – 241	123 152	192 – 414	229	-

The consequence of selecting the exposure conditions for examination is to provide X-ray image but also to expose the patient to ionizing radiation. The presented data indicate that the difference in doses that patients received in the same medical procedure in different healthcare entities are even more than 10-fold differences. The broadest ESD value range was found in radiography of the thoracic spine in the projection AP and LAT. The projection LAT measured values were in the range of 523 to 10550 μGy (average 2175 μGy). Similarly, the span in measured doses was observed in radiography of the spine lumbosacral in both projections. For example, in the LAT projection the span of measured dose was within a range from 1180 to 23730 μGy (average 6939 μGy). The narrowest ESD range was found in radiography of the elbow joint projections AP and LAT. For this test, the highest value of the measured dose to the lowest value was below 3. It should also be noted that the reference values were not exceeded in any dose examination.

When performing some of the X-ray examination it is necessary to take more exposure on different surfaces. This allows for complete visualization of illness changes in a patient's body. However, the patient is exposed to a higher dose of ionizing radiation. The results received on the entrance surface dose are set out in Figure 1.

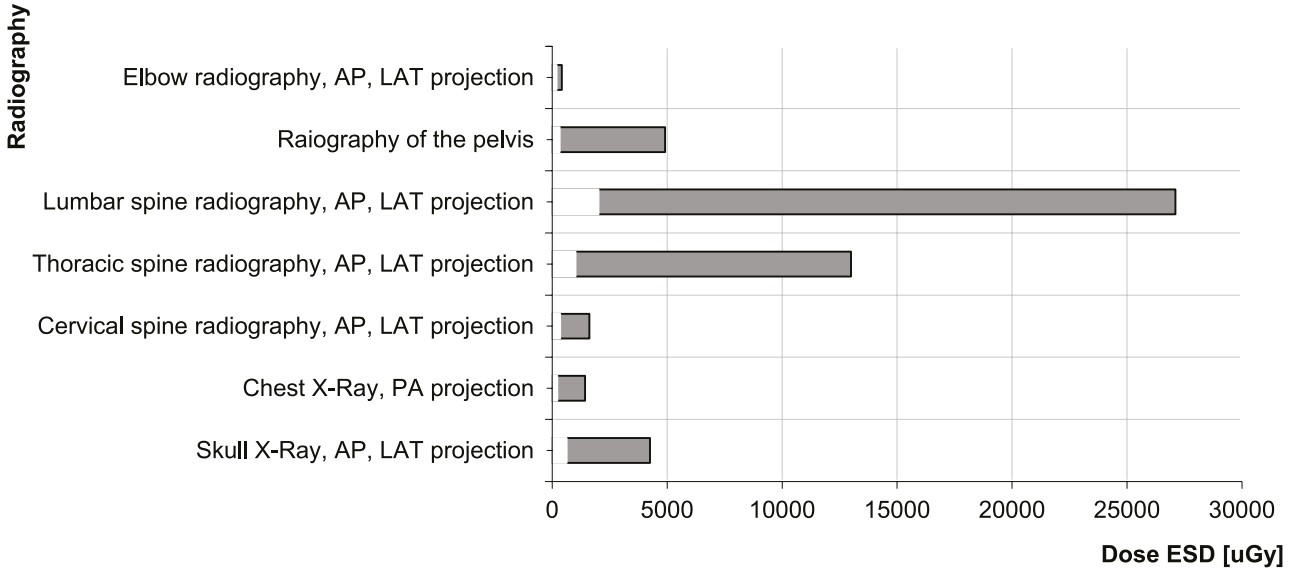

Figure 1. Entrance surface doses (ESD) received by adult patients during some conventional radiography X-ray examinations

In the given example a large range of ESD doses received by patients is also observed. The highest adult dose the patient receives was during radiography of the spine lumbosacral. The range of doses was measured from 2014 to 27102 μGy (average 9512 μGy). On the contrary, the lowest dose throughout the study the patient receives was during radiography of the elbow. The scope of the measured doses was within a range from 192 to 414 μGy with a average value 229 μGy.

DISCUSSION

The obtained results show that the ESD dose the patients receive do not exceed the reference values in Poland [11]. It is advantageous for the patient since he is exposed to a lower dose of ionizing radiation. Thus, there has been improvement in comparison with earlier research, which indicated cases of exceeding the reference dose [2]. The range of ESD doses recorded in relation to previous research has also changed. An example would be the lumbar spine radiography in the AP projection. In previous examinations, the range of measured dose was from 516.8 μGy to 10 062 μGy with the average value 2685.7 μGy . Currently recorded ESD doses for this examination were in the range from 418 μGy to 5170 μGy with average value of 1492 μGy. Not in every case the reduction in the dose received by the patient was reported. During skull radiography in two projections (AP and LAT) a slight increase in ESD doses was found. In case of the AP projection the range of measured doses was from 326 μGy to 2840 μGy with the average value 968 μGy. The results from year 2012 indicated a slightly different range of doses received: from 203.9 μGy to 2195.5 μGy and the average value was 894.4 μGy. It should be noted, however, that despite the increase in the value of measured ESD doses for selected examinations the reference values were not exceeded. Currently measured values of ESD doses also differ from those recorded in other European countries [5, 6, 9].

Having analyzed the selected exposure conditions (high voltage) it can be observed that X-ray rooms do not always use the parameters defined in the standard procedures. This can be explained by a long-standing habit of X-ray room personnel to select their own exposure conditions. As a result, X-ray technicians still use them and it is reflected in the working procedures. It should noted that the requirement to develop working procedures has been defined in the Regulation of the Minister of Health in 2007 [10]. The regulation impose the form and content requirements for standard and working procedures. At the same time it does not clarify a number of important issues. First of all, the regulation does not indicate explicitly personnel responsible for the preparation of operating procedures, only impose the need to look at them. The lack of this clarification leads to a situation in which the procedures are created by people that do not have full knowledge in this area or the procedures are not prepared at all. This applies in particular healthcare entities where X-ray technicians are employed only on contracts and perform only the X-rays examinations. The creation of working procedures is included in the scope of duties of the radiological protection inspector, however, this is not his statutory task. Standard procedures have also become an additional and unexpected problem. At the moment, there are two editions of standard procedures [7, 8]. The latest one from 2015 year supplemented with missing radiological procedures does not repeal the previously issued standard procedures. The documents also

contain a number of minor deficiencies that hinder their use. An example could be the lack of table of contents and page numbers corresponding to each standard procedures. The document has also more than 3,200 pages and contains minor mistakes on the method of performing the X-ray examinations. For this reason the next edition of the document was announced. All of these errors result in the discouragement of medical staff to reach for them. Therefore, it seems necessary to introduce changes that will encourage medical personnel to use them. This would help to further improve the quality of medical services and reduce patient exposure to ionizing radiation.

CONCLUSIONS

1. It was found that ESD doses received by the patients did not exceed the reference levels of ESD. The measured ESD values do not differ from those recorded in other European countries.
2. It is necessary to update immediately the standard procedures and to develop detailed guidelines for the preparation of working procedures in X-ray rooms in healthcare entities.
3. It is necessary to continuously improve the awareness of personnel ordering and performing X - ray examinations about the effects of ionizing radiation on the human body.
4. The obtained results should be helpful for doctors when deciding to direct a patient for X-ray examination.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1. *Bekas M., Gajewski AK., Pachocki K.:* How often are X-rays used as diagnostic tool by healthcare providers in the Masovian province of Poland. Rocz Panstw Zakl Hig. 2013;64(2):155–60.
2. *Bekas M., Pachocki K.:* The dose received by patients during dental X-ray examination and the technical condition of radiological equipment. Med Pr. 2013;64(6):755–9, http://dx.doi.org/10.13075/mp.5893.2013.0074
3. *Bekas M., Pachocki K., Waśniewska E., Bogucka D., Magiera A.*: Assessing the dose values received by patients during conventional radiography X-ray examinations and the technical condition of the equipment used for this purpose. Med Pr. 2014;65(6):715–21, http://dx.doi.org/10.13075/mp.5893.00044.
4. *Bekas M., Pachocki K.A., Waśniewska E., Bogucka D., Magiera A.*: Dosages of ionizing radiation during limb diagnostic X-Ray examinations. Med Pr. 2016;67(3):321–26, http://dx.doi.org/10.13075/mp.5893.00371.
5. *Hart D, Wall BF, Hillier MC, Shrimpton PC.*: Frequency and collective dose for medical and dental X-ray examinations in the UK, 2008. Report No. HPA-CRCE-012. Oxfordshire: Health Protection Agency, Centre for Radiation, Chemical and Environmental Hazards; 2010.
6. Institut de Radioprotection et de Surete Nucleaire. French population's exposure to ionizing radiation associated with medical diagnostic procedures in 2012. Rapport PRP-HOM No. 2014-6. Paris: The Institut; 2014. (in French)
7. Notice of the Minister of the Health of 31 December 2014 on the publication of the list of best practice in the field of radiology – Diagnostic imaging and interventional radiology. Off J Ministr Health 2014, No. 85. (in Polish)
8. Notice of the Minister of the Health of 10 November 2015 on the publication of the list of best practice in the field of radiology – Diagnostic imaging and interventional radiology. Off J Ministr Health 2015, No. 78. (in Polish).
9. Radiation Protection No 180. Medical Radiation Exposure of the European Population. Part 1/2. European Commission; 2014, Brussels, Belgium. Luxembourg: Office for Official Publications of the European Communities; 2014.
10. Regulation of the Minister of the Health of 2 February 2007 on requirements on the detailed requirements for the form and content of the working standard and medical radiological procedures. J Laws 2007, No. 24, item 161. (in Polish).
11. Regulation of the Minister of the Health of 18 February 2011 on requirements for safe of ionizing radiation for all types of medical exposure. J Laws 2011, No. 51, item 265. (in Polish)

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