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ORIGINAL PAPER

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DOSAGES OF IONIZING RADIATION DURING LIMB DIAGNOSTIC X-RAY EXAMINATIONS

DAWKI PROMIENIOWANIA JONIZUJĄCEGO W RENTGENOWSKICH BADANIACH DIAGNOSTYCZNYCH KOŃCZYN

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Abstract

Background: X-ray examination is associated with the patient's exposure to ionizing radiation. The dose values depend on the type of the medical procedure used, the X-ray unit technical condition and exposure conditions selected by X-ray technicians. The aim of this study has been to assess the entrance surface dose (ESD) values received by patients during the limb X-ray examination. The results should help doctors in making the decision about sending patients for X-ray examination. At the same time the X-ray unit condition and examination method performance are important for the radiological protection of the medical staff. **Material and Methods:** The study covered the total number of 118 X-ray units located in 56 public healthcare entities and private medical centers in the Masovian Voivodeship. The measurement of the radiation dose rate received by patients was based on our own research procedures. **Results:** The research has found that there are even more than 10-fold differences in the dose values received by adult patients with several-fold differences in the case of children patients. The broadest dose value range for adult patients was related to femur radiography. The ESD values for this procedure ranged 70.9–765.2 μGy (with the average value of 319.7 μGy). The broadest dose value range for children was related to the knee radiography. The range for children aged 5 years old was 11.8–95.8 μGy (with the average value of 48.9 μGy). **Conclusions:** It is essential to immediately implement X-ray room working procedures for the purpose of performing diagnostic examinations based on the existing model procedures. Med Pr 2016;67(3):321–326

Key words: X-ray, conventional radiology, entrance surface dose (ESD), limbs, medical procedures, X-ray examinations

Streszczenie

Wstęp: Badania rentgenowskie wiążą się z narażeniem pacjentów na promieniowanie jonizujące. Wielkość narażenia zależna jest od wykonywanej procedury medycznej, stanu technicznego aparatu rentgenowskiego i warunków ekspozycji dobieranych przez techników rentgenowskich (rtg.). Celem badania było oszacowanie wejściowej dawki powierzchniowej (ESD), na którą są narażani pacjenci podczas badań rentgenowskich kończyn górnych i dolnych. Uzyskane wyniki powinny być brane pod uwagę przez lekarzy przy podejmowaniu decyzji o kierowaniu pacjentów na badanie rentgenowskie. Stan techniczny aparatów rtg. i sposób wykonania badania jest również istotny dla ochrony radiologicznej personelu medycznego. **Materiał i metody:** Badaniami objęto 56 placówek medycznych zlokalizowanych na terenie województwa mazowieckiego, wyposażonych łącznie w 118 aparatów rentgenowskich. Pomiary dawek otrzymywanych przez pacjentów przeprowadzono, stosując autorskie akredytowane procedury badawcze. **Wyniki:** Stwierdzono kilkunastokrotne różnice w wielkości dawek otrzymanych przez dorosłych pacjentów i kilkukrotne różnice w przypadku dzieci. Największa rozpiętość mierzonych dawek u pacjentów dorosłych dotyczyła radiografii kości udowej. Zmierzona ESD dla tej procedury wynosiła 70,9–765,2 μGy (średnia: 319,7 μGy). U dzieci największa rozpiętość mierzonych dawek dotyczyła radiografii kolana. Wejściowa dawka powierzchniowa u dzieci 5-letnich wynosiła 11,8–95,8 μGy (średnia: 48,9 μGy). **Wnioski:** Niezbędne jest jak najszybsze wdrożenie w pracowniach rentgenowskich roboczych procedur badań diagnostycznych na podstawie obowiązujących w Polsce procedur wzorcowych. Med. Pr. 2016;67(3):321–326

Słowa kluczowe: promieniowanie X, radiologia ogólna, wejściowa dawka powierzchniowa (ESD), kończyny, procedury medyczne, badania rentgenowskie

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INTRODUCTION

X-ray examination, including but not limited to limb examination, is a popular and universally used injury and disease diagnostic method. Its main aim is to assess post-traumatic developments, verify suspected fractures or dislocations, and diagnose inflammatory or degenerative condition or developmental defects.

A distinctive X-ray examination feature is that it may be done quickly and at a relatively low cost, while its output – an X-ray image is virtually accessible in no time at all. On this account you can see a continuous increase in the number of the X-ray examination performed [1]. For the X-ray examination output to be correct, the X-ray technician must take into account a number of factors influencing the X-ray image quality, i.e., exposure conditions selected based on the medical procedure applied, the patient body constitution, the X-ray image recording method [2–4], and the X-ray unit technical condition.

The factors mentioned above have also a significant impact on the size of the patient's exposure to radiation. X-ray radiation carries the risk of inducing additional cancers. It is estimated that each year from several dozens to several thousand patients develop a different kind of cancer in each country where X-ray medical examinations are performed [5].

When sending the patient for X-ray examination the doctor often faces the dilemma of whether to perform such examination, given its negative effects for the patient. The doctor does not always have access to source information on the size of the doses, to which a patient is exposed during the examination. In general the doctor is unable to determine whether the examination is less or more aggravating for the patient.

In the referral the doctor determines only the type and purpose of the examination, diagnosis and other supporting information to allow the technician to conduct the X-ray examination correctly. The doctor does not receive feedback on the size of the entrance surface dose (ESD), for which the patient has been exposed.

The aim of this study has been to assess the dose values received by patients during the upper and lower limb X-ray examination. The results should help doctors in making the decision about sending patients for X-ray examination. This study is complementary to the earlier research which focused on other X-ray procedures [6]. The examinations were conducted in the Masovian Voivodeship since it is the biggest voivodeship in Poland with the highest number of inhabitants. There is also the largest number of X-ray units available for examinations (as compared to other voivodeships).

MATERIAL AND METHODS

At the outset of the study it was necessary to determine the number of X-ray units used in the Masovian Voivodeship. For this purpose the MZ-52 report (prepared annually by the Voivodeship Sanitary-Epidemiological Station in Warsaw, Poland) was used.

Based on the report it had been found that there were 563 conventional radiography X-ray units used in the voivodeship. The units were located mainly in hospitals, local clinics, and private medical centers. Knowing the number of X-ray units in use, some preliminary (pilot) research was carried out to determine the sample size for the main research. It was decided that the analysis should have covered at least 63 units, while finally the measurements were performed on 118 X-ray units in 56 health facilities [6].

Among the selected X-ray units, the units with computed radiography (CR) and direct radiography (DR) type of image recording (75.4%) dominated. When choosing the facilities, its type (a hospital, clinic, or private medical center) and location (the capital city of Warszawa, Poland, and other voivodeships' cities) were taken into account. Before commencing to measure the dose values received by patients, each time the technical condition of the X-ray unit had used to perform the conventional X-ray examination had been assessed [6,7], according to the applicable regulations of the Minister of Health [3].

Tests were carried out based on our own accredited procedure, which verified device parameters including but not limited to high-voltage generator operation, exposure time consistency, X-ray focal spot size [7]. Independently of the X-ray unit technical condition assessment results, entrance surface dose values were measured (also for non-compliant X-ray units in medical centers). To measure entrance surface dose values, Diados E (PTW, Germany) and Xi (Unfors RaySafe, Sweden) dosemeters (with valid calibration certificates) were used. According to the applicable procedure, the dose detectors were placed on a body phantom. The phantom was made of polymethyl methacrylate (PMMA). The backscatter factor was also taken into account.

In each X-ray room the X-ray technician was asked to recreate exposure conditions for each used X-ray unit based on the patient medical records of adults and children (aged 5, 10, and 15 years old). Each time the technician's task was to select the exposure conditions most

commonly used for a given age group, type of examination and the type of image recording, including high voltage values (kV), the distance between the X-ray focal spot and the body phantom, as well as current exposure time values (mAs). The ESD was recorded for the medical procedures, such as the upper and lower limb X-ray examination. The procedures included femur, knee, foot, hand, elbow, and forearm radiography.

RESULTS

The exposure conditions and entrance surface doses values were recorded and measured for 1264 cases overall. The high voltage (kV) and current exposure time values (mAs), and distribution values selected by X-ray technicians in the Masovian Voivodeship are presented in the Figure 1 and 2.

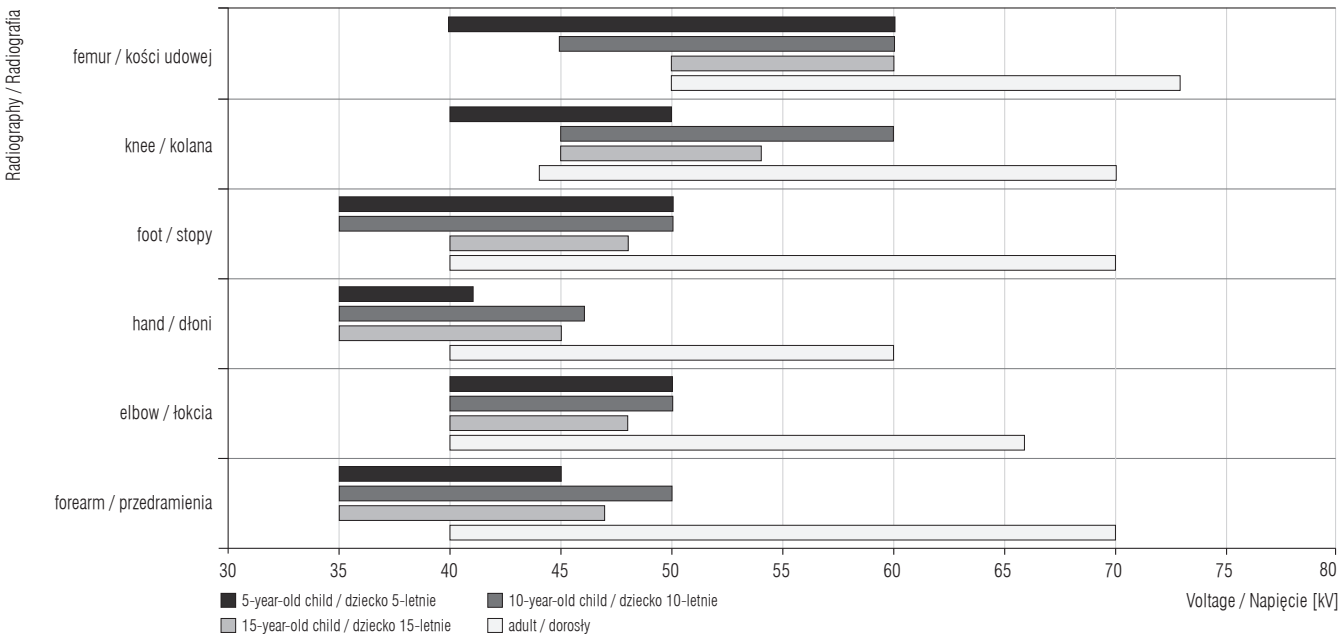

Fig. 1. High voltage values selected by technicians during some conventional radiography X-ray examinations
Ryc. 1. Wartości wysokiego napięcia dobierane przez technika podczas wybranych ogólnodiagnostycznych badań rentgenowskich

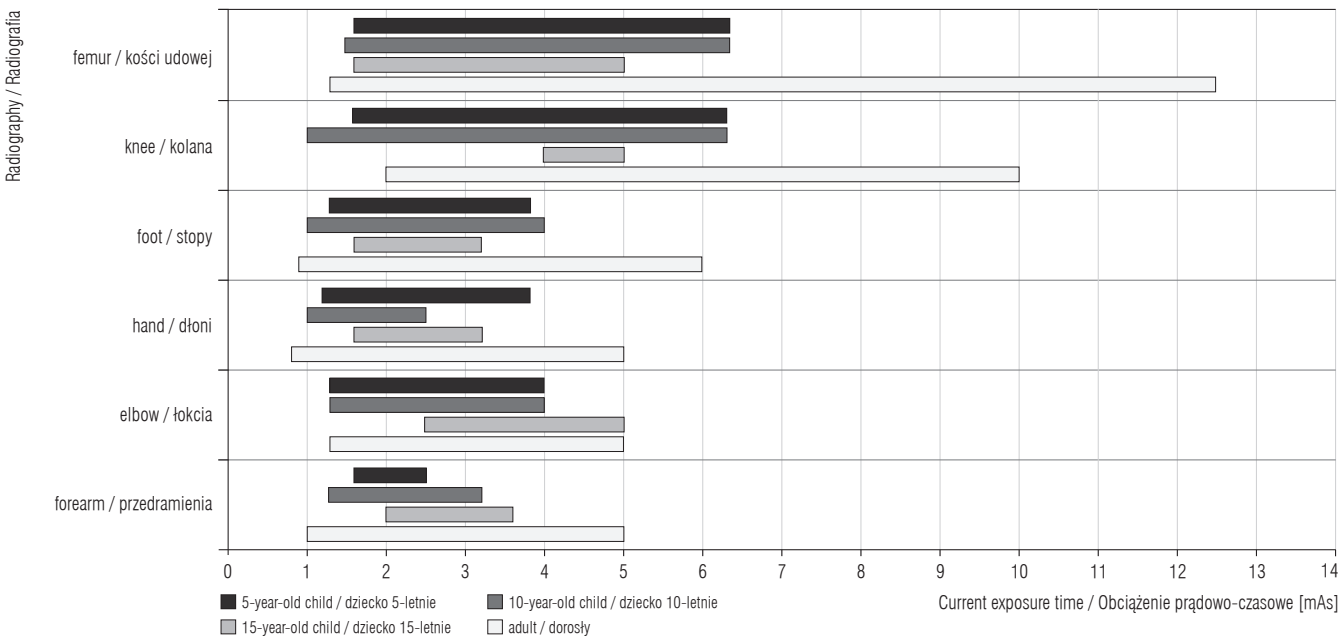

Fig. 2. Current exposure time values selected by technicians during some conventional radiography X-ray examinations
Ryc. 2. Wartości obciążenia prądowo-czasowego dobierane przez technika podczas wybranych ogólnodiagnostycznych badań rentgenowskich

The results indicate that the range of the selected high voltage and current exposure time values for the analyzed X-ray procedures is broad. In the case of the adult forearm radiography it has been found that the voltage ranged 40–70 kV (with the average value of 52 kV). In the same case the current exposure time values range 1–5 mAs (with the average value of 3.2 mAs). The adult femur radiography is also performed in the broad range of exposure conditions. In this context particular attention should be paid to current exposure time values. They range here 1.3–12.5 mAs (with the average value of 5.9 mAs).

The exposure condition range selected for children was lower than for adults. The narrowest high voltage range was found for the hand radiography of children aged 5 years old. The selected values range 35–41 kV (with the average value of 40 kV). The highest high voltage range selected for children was found for the foot,

Table 1. Entrance surface doses (ESD) received by patients during some conventional radiography X-ray examinations
Tabela 1. Wejściowe dawki powierzchniowe (ESD) otrzymywane przez pacjentów podczas wybranych ogólnodiagnostycznych badań rentgenowskich

Radiography Radiografia	ESD [μGy]							
	5-year-old child dziecko 5-letnie		10-year-old child dziecko 10-letnie		15-year-old child dziecko 15-letnie		adult dorosły	
	R	M	R	M	R	M	R	M
Femur / Kości udowej	52.1–95.9	65.6	29.4–154.3	84.3	67.0–226.5	159.4	70.9–765.2	319.7
Knee / Kolana	11.8–95.9	48.9	44.7–80.8	67.3	107.1–165.1	126.8	97.7–543.6	224.6
Foot / Stopy	17.3–37.8	24.4	11.3–46.7	28.8	18.5–62.2	40.1	31.1–143.5	60.6
Hand / Dłoni	12.1–30.2	19.2	8.1–30.2	21.6	26.2–37.1	32.1	20.9–69.8	34.7
Elbow / Łokcia	17.3–69.4	34.3	17.7–62.8	36.7	42.0–89.1	66.9	40.4–145.9	82.6
Forearm / Przedramienia	17.3–42.7	29.2	17.7–43.5	31.9	40.3–75.6	52.1	38.9–165.3	85.3

R – range / zakres, M – mean / średnia.

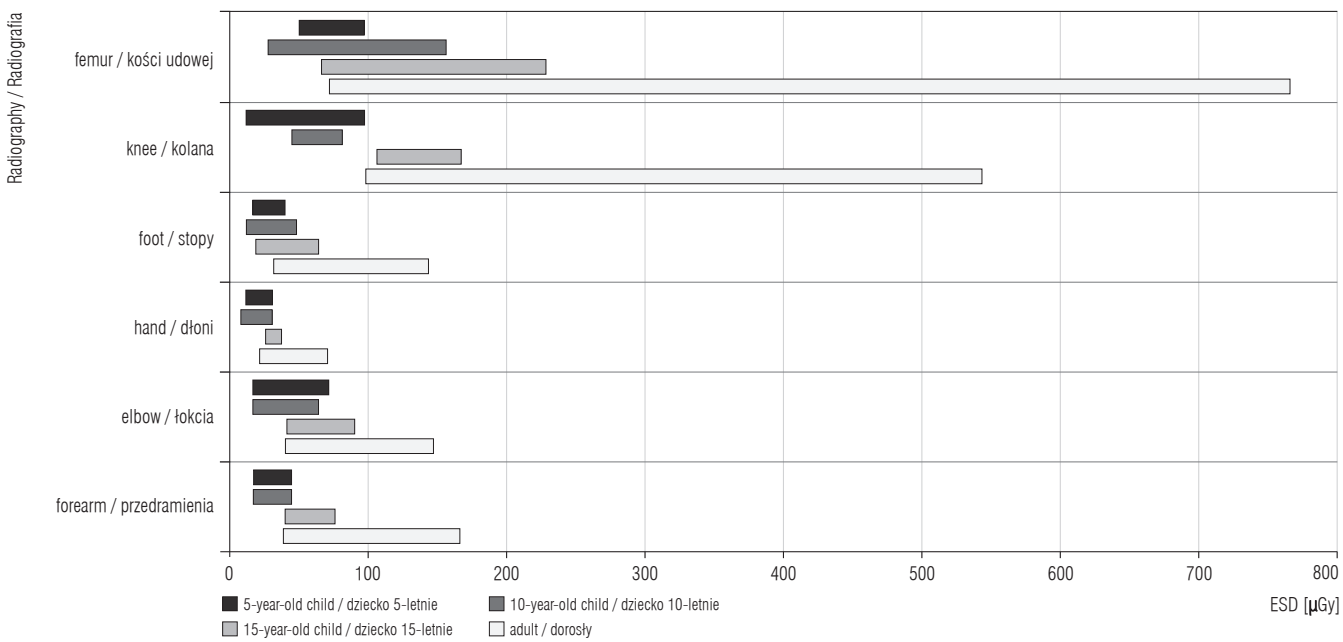

Fig. 3. Entrance surface doses (ESD) received by patients during some conventional radiography X-ray examinations – illustration of the data from Table 1
Ryc. 3. Wejściowe dawki powierzchniowe (ESD) otrzymywane przez pacjentów podczas wybranych ogólnodiagnostycznych badań rentgenowskich – ilustracja danych z tabeli 1

femur and forearm radiography. In the case of those examinations the high voltage range breadth was 15 kV. The current exposure time values selected for all children age groups range 1–6.3 mAs.

Well-selected exposure conditions and well-performed X-ray examination lead to a high quality X-ray image. Nevertheless, X-ray examination is associated with the patient's exposure to ionizing radiation. Entrance surface dose values received by patients during certain X-ray examinations are set out in the Table 1 and Figure 3.

It has been found that there is even more than 10-fold difference in the dose values received by adults during the same medical procedure. The broadest dose value range was observed for the femur radiography. The ESD values for this procedure ranged 70.9–765.2 μGy (with the average value of 319.7 μGy). The lowest dose values were observed for the hand radiography. The ESD values for this procedure ranged 20.9–69.8 μGy (with the average value of 34.7 μGy). In the case of younger patients (aged 5, 10, and 15 years old) smaller differences in the received dose values were observed. The broadest ESD values range was observed for the 5-year-old children's knee radiography. The range in that case was 11.8–95.8 μGy (with the average value of 48.9 μGy). The narrowest ESD range was observed for the 15-year-old children's hand radiography. The range in that case was 26.2–37.18 μGy (with the average value of 32.1 μGy).

DISCUSSION

The research results show that entrance surface dose values received by patients in every age group in the course of the same X-ray examination differ visibly. The ESD exposure depends largely on the way the X-ray examination is performed by the technicians.

The research results indicate that in the course of the same diagnostic procedure the medical personnel in various medical centers sets different values for high voltage (kV) and current exposure time (mAs). Those parameters directly impact the dose value received by patients. A good example that supports this observation is the adult femur radiography. The dose values received by patients range here 70.9–765.2 μGy. The selected high voltage values for the adult femur radiography ranged 50–73 kV, while the current exposure time values ranged 1.3–12.5 mAs.

It should be mentioned that although the selected exposure conditions range is broad, the recorded entrance surface dose values do not diverge from the values recorded in other European countries [8–10]. In the case of the femur radiography for an adult patient, an average ESD value is 319.7 μGy as compared to the United Kingdom (UK) where such a test involves obtaining the ESD value of 400 μGy.

Similarly, in the case of the knee radiography the average ESD value for an adult patient is 224.6 μGy, while in the UK – it is 200 μGy. Based on the above research results it should also be noted that the uniform X-ray examination procedure implementation seems to be necessary. In Poland, the work on developing uniform X-ray procedures had already been done and on December 31, 2014 the X-ray examination standard procedures were published [11]. Every X-ray room performing X-ray diagnostic examinations has to develop now its own working procedures based on those standard procedures. Unfortunately, due to not clear legal regulations there are no explicit guidelines indicating who should develop those procedures. This leads to problems with its development and application processes [12].

The research results may help doctors directing patients to X-ray examinations. Information on the dose, at which a patient is exposed, should make doctors consider alternative methods of diagnosis. The doctors should also be aware of the effects of radiation on the human body, and thus should increase their knowledge in this field, regardless of legal requirements.

It should be noted that the dose received during the limb X-ray examinations is not relatively high as compared to other X-rays procedures [6].

CONCLUSIONS

1. It is essential to immediately implement in X-ray rooms suitable diagnostic examination working procedures based on the existing model procedures.
2. It is essential to constantly improve the examination quality and to raise awareness about the X-ray exposure effects on the human body among those who order and conduct such examinations.
3. The recorded entrance surface dose values do not differ significantly from the values recorded in other European countries.

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