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Bećo Pehlivanović
University of Bihać, Pedagogical faculty,
Department of mathematics and physics

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Estimation of patient doses in radiological diagnostics in the cantonal hospital Dr. Irfan Ljubijankic, Bihac

Abstract: This article presents the results of measuring patient doses during X-ray diagnostics at the "dr Irfan Ljubijankić" Cantonal Hospital in Bihać. Measurements of the entrance skin dose were also performed in this paper, based on which the effective dose was estimated. The research was carried out on 256 patients who received doses during seven X-ray examinations. The results of measuring the mean value of the entrance skin dose were performed during the examination of the lung posteroanterior (PA) 0.26 mGy, cervical spine anteroposterior and lateral 1.03 mGy and 0.40 mGy (AP, LAT), lumbar spine anteroposterior and lateral 3.20 mGy and 2.10 mGy (AP, LAT), pelvis anteroposterior 1.29 mGy(AP) and knees anteroposterior 0.41 mGy (AP). Based on these results, the mean values of the effective doses were obtained: 0.02 mSv, 0.04 mSv, 0.03 mSv, 0.41 mSv, 0.12 mSv, 0.08 mSv and 0.03 mSv respectively. Exposures for all radiographic procedures in our work are in accordance with European standards and generally less than in other European countries.

Keywords: X-ray, X-ray tube, diagnostic radiology, entrance skin dose, effective dose, radiation protection

1. Introduction

X-ray radiation is produced artificially by bombarding a target (anode, anticathode) with fast electrons, accelerated in the electronic, so-called X-ray tube, or in particle accelerators (linear accelerator, betatron), and it naturally occurs during changes in the atomic shell caused by nuclear processes. X-rays are, therefore, electromagnetic waves, such as visible light, radio and TV waves, infrared, ultraviolet and gamma rays. The wavelength of X-rays ranges from several nanometers to hundredths of a nanometer (from 10^{-9}m to 10^{-11}m), which means that it is thousands of times smaller than the wavelength of visible light (from 4×10^{-7}m to 7×10^{-7}m).

X-ray diagnostic machines are the oldest and one of the most commonly used artificial sources of ionizing radiation. They are currently a part of every patient's life and used in almost all stages of the treatment of any problem.

Exposure to artificial sources is limited, ie reduced to an acceptable level. It is of particular importance to reduce unnecessary exposure, which is achieved by applying the basic principles of radiation protection: justification of the practice, optimizing radiation protection and limiting individual doses and risks [1]. The justification of practice in diagnostic radiology should be viewed in the same way as the justification of other medical exposures to ionizing radiation: the practice is justified if the benefit to the exposed individual or society as a whole is greater than the harm caused by exposure to ionizing radiation. Optimizing protection in diagnostic radiology is in essence, finding a compromise between the quality of the diagnostic information provided by an X-ray, and the dose received by the patient. The risk of malignant diseases is associated with exposure to ionizing radiation. It can be said that the risk is proportional to the dose received by the individual. That is why the biological effects that can arise from the exposure of the organism to ionizing radiation are considered and a risk assessment is carried out in order to avoid exposures that are not necessary.

All exposures to ionizing radiation needs to justified and optimized in terms of the benefit and risks (ICRP, 1991).

Dosimetric quantities commensurate with patient risk (equivalent tissue or organ dose, effective dose, delivered energy) cannot be measured directly. By applying standard procedures, they can be evaluated based on the results of measurements of directly measured quantities. Considering the number of approximations that are introduced during the assessment and the resulting measurement uncertainties, entrance skin doses (ESD) represent a practical and reliable indication of the level of patient exposure. Based on entrance skin doses, the effective dose (ED) received by the patient is calculated [2].

2. Materials and Methods

2.1. Methodology

This research was conducted at the "Dr Irfan Ljubijankić" Cantonal Hospital in Bihać according to the guidelines specified in the European Commission Guidelines (EC, 1999). In this study, a direct method of dose assessment was adopted using thermoluminescent dosimeters, TLD-100 (LiF: Mg, Ti). Calibrated LiF dosimeters (TLD chips) were used to measure the entrance skin dose (ESD) on 256 patients undergoing routine diagnostic examinations, where all patients gave their consent for the use of measurement results for scientific purposes. In accordance with the protocol for quality control in conventional radiography, measurements were made on the x-ray imaging device GE Healthcare Definium 6000. The GE Healthcare Definium 6000 is a state-of-the-art digital X-ray system offering exceptional image quality and versatile applications in diagnostic radiology. With its high-resolution digital detector technology, it delivers detailed and clear images. The system features automatic exposure control (AEC) to ensure optimal image quality with minimal radiation dose [3].

The measurements included: visual inspection and functionality of the mechanical parts of the X-ray machine, testing the accuracy and repeatability of the X-ray tube voltage, testing the accuracy and repeatability of the exposure time, repeatability and linearity of the radiation output, radiation output as a function of the X-ray tube voltage, total filtration and half-attenuation thickness, and examination of the limitation of X-ray beam propagation.

2.2. Entrance skin dose (ESD)

The outputs of the X-ray machines (mGy/mAs) were determined based on the American Association of Physicists in Medicine (AAPM) no. 61 Protocol (Ma et al., 2001). Once the tube potential, the tube current, the exposure time and the focus to skin distance (*d*) are known, ESD can be expressed as [4]:

$$ESD = O \times \left(\frac{V}{80}\right)^2 \times \left(\frac{100}{d}\right)^2 CTf \qquad (1)$$

where O is the tube output determined units of mGy/mAs, V is the tube voltage in kV, d is the focus to skin distance in cm, C is the current in mA, T is the exposure time in s, and f is the backscatter factor. The tube calibration is performed at 80 kV, 1 m distance and 10 mAs.

2.3. Effective dose (E)

Effective doses, E (given in μSv). It is formed by weighting H_T, by the tissue weighting factor (W_T) and summing over the tissue. Effective dose can be represented as [5]

$$E = \sum_T W_T H_T \qquad (2)$$

3. Results and Discussion

During each radiological procedure, the following data on the patient and the radiographic technique were collected: sex, age, body mass and height of the patient; type of diagnostic procedure; parameters of the radiographic technique: x-ray tube voltage, product of current strength and exposure time, film size and focus-film distance [6].

The scale of each patient exposure analysis is limited for selected procedures. In order to assess the exposure of patients during classic radiographic procedures, dose measurements were performed on the x-ray imaging device GE Healthcare Definium 6000 at "Dr Irfan Ljubijankić" Cantonal Hospital in Bihać. The analysis includes the following types of diagnostic procedures: lungs posteroanterior (PA); cervical spine anteroposterior and lateral (AP, LAT); lumbar spine (AP, LAT); pelvis (AP); knees (AP). Table 1 shows the patients characteristics and the technical parameters for the various examinations at "Dr Irfan Ljubijankić" Cantonal Hospital in Bihać selected for the study.

Table 1. Summary of patients characteristics and technical parameters selected for the various examinations at "Dr Irfan Ljubijankić" Cantonal Hospital in Bihać selected for the study.

Examination	Projection	Number of Patients	Age range (mean)	kVp range (mean)	mAs range (mean)
Lungs	PA	56	25-71 (44)	65-90 (80.5)	12.5-30 (25.5)
Cervical spine	AP	19	25-76 (39)	60-80 (74.5)	13.5-40 (24.2)
Cervical spine	LAT	18	26-74 (43)	60-80 (74.5)	16-45 (23.2)
Lumbar spine	AP	32	25-77 (58)	70-95 (86.0)	20-50 (42.2)
Lumbar spine	LAT	32	26-73 (55)	80-95 (89.0)	30-60 (40.3)
Pelvis	AP	47	25-78 (71)	60-85 (77.5)	12.5-45 (28.0)
Knees	AP	52	26-70 (42)	50-80 (72.5)	12.5-30 (25.5)

Shown in Table 2 is the estimated (ESD) and effective dose (ED) for all projections and examinations. For all examinations and projections, the ESD ranged from a minimum of 0.05 mGy to the maximum of 7.35 mGy and the effective doses were 0.0051 mSv–0.95 mSv with the respective mean ESD and ED ranges as 0.26–3.20 mSv and 0.02–0.41 mSv.

Table 2. Estimated entrance skin dose (ESD) and effective dose (ED) for all projections and examinations from conventional radiograph examinations.

Examination	Projection	Entrance skin dose (mGy)		Effective dose (mSv)	
		Range	Mean	Range	Mean
Lungs	PA	0.05-4.20	0.26	0.0051-0.93	0.02
Cervical spine	AP	0.30-2.52	1.03	0.0077-0.05	0.04
Cervical spine	LAT	0.25-1.35	0.40	0.0029-0.08	0.03
Lumbar spine	AP	0.97-7.35	3.20	0.05-0.95	0.41
Lumbar spine	LAT	0.95-4.32	2.10	0.08-0.52	0.12
Pelvis	AP	0.19-2.25	1.29	0.049-0.75	0.08
Knees	AP	0.28-0.77	0.41	0.003-0.09	0.03

The mean value of the entrance skin dose (ESD) in comparison with published works all over the world and internationally established diagnostic reference levels (European Commission, United Nations Scientific Committee on the Effects of Atomic Radiation) does not differ from the values given in these works and the recommendations they provide internationally established diagnostic reference levels [7, 8, 9,10] . Variations in patient doses may be due to the speed class of film and screen combinations, manual exposure control settings, patient size, and other equipment-related factors.

The mean effective doses for the studies were lower than those published elsewhere. This can generally be attributed to the good radiographic techniques used during the procedure.

4. Conclusions

In accordance with the protocol for quality control in conventional radiography for the needs of our work, measurements were made on the x-ray machine GE Healthcare Definium 6000 for imaging at “Dr Irfan Ljubijankić” Cantonal Hospital in Bihać. In order to prevent unnecessarily large doses for the patient, a minimum filtration criterion is introduced, and a minimum radiation output exists in order to keep the exposure time reasonably short and to prevent artifacts due to the patient's movement. This also applies in our case.

The values obtained compares favorably with similar works published elsewhere and internationally established diagnostic reference levels. This shows that when technical and clinical factors are optimized, patient doses will reduce substantially.

The purpose of this article is to present effective doses from various procedures because effective dose is a measure of potential detriment. It is hoped that this information will be of value to those performing procedures involving ionizing radiation, as well as to referring physicians and other entities such as institutional research committees.

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Sažetak

U radu su prikazani rezultati mjerenja pacijentnih doza u konvencionalnoj rendgenskoj dijagnostici provedeni u Kantonalnoj bolnici „Dr. Irfan Ljubijankić" u Bihaću. Mjerenja ulazne kožne doze (entrance skin dose, ESD) korištena su za procjenu efektivne doze pacijenata. Istraživanje je obuhvatilo ukupno 256 pacijenata, koji su bili izloženi jonizirajućem zračenju tokom sedam standardnih radiografskih procedura.

Srednje vrijednosti ulazne kožne doze iznosile su: za radiografiju pluća u projekciji odostraga prema naprijed (PA) 0,26 mGy; za radiografiju vratne kralježnice u projekcijama od naprijed prema nazad i bočno 1,03 mGy i 0,40 mGy (AP, LAT); za radiografiju lumbalne kralježnice u istim projekcijama 3,20 mGy i 2,10 mGy (AP, LAT); za radiografiju zdjelice u AP projekciji 1,29 mGy; te za radiografiju koljena u AP projekciji 0,41 mGy.

Na osnovu izmjerenih ESD vrijednosti izračunate su srednje efektivne doze, koje su iznosile 0,02 mSv, 0,04 mSv, 0,03 mSv, 0,41 mSv, 0,12 mSv, 0,08 mSv i 0,03 mSv, respektivno. Dobijeni rezultati ukazuju da su izlaganja pacijenata za sve analizirane radiografske procedure u skladu s evropskim referentnim dijagnostičkim nivoima, te su u većini slučajeva niža u poređenju s podacima objavljenim za druge evropske zemlje.

Adresa:
Bećo Pehlivanović
University of Bihać
Pedagogical faculty
Department of mathematics and physics
E-mail: pbeco@hotmail.com;
beco.pehlivanovic@unbi.ba;