Evaluation of the entrance surface radiation dose for patients undergoing selected extremity X-ray examination in Al Hakeem General Hospital, Iraq

[1]Allawi Hamead Harjan, [2]Shihab Ahmed Jasim, [1]Hussien Abid Ali Mraity, [1,3]Ali Jaafar Azeez, [1]B.A. Almayahi, [1]Azhar S. Alaboodi

[1] Department of Physics, Faculty of Science, University of Kufa, Iraq

[2]Faculty of Agriculture, University of Kufa, Iraq

[3]Department of Radiology Techniques, College of Medical Technology, The Islamic University, Najaf, Iraq

Corresponding Author: basim.almayahi@uokufa.edu.iq

Abstract

In this research, radiation doses (ESD) were estimated for patients undergoing some extremity x-ray examination in Al Hakeem General Hospital. Radiographic exposure factors (e.g. tube potential (kVp), tube loading (mAs) and distance) that affect the amount of dose were collected for each patient. The ESD was calculated by applying a given mathematical equation. In this study, four medical X-ray examinations (arm, wrist, ankel and knee) were considered. The latter examination was taken in postero-anterior (PA) projection. This study includes 86 patients from adult (men and women). The resulting data in room 1,2 show that the arm examination range had its lowest values 0.07, 0.06 mGy and its highest values 0.48, 0.44 mGy, respectively, while the results of the wrist examination were: the lowest values 0.25, 0.31 mGy and the highest values 0.94, 1.43 mGy respectively. The lowest values of ESD for the ankle were 0.26 and 0.29 mGy and its highest values were seen to be 0.55 and 0.31 mGy respectively, and the results of the knee examination showed that its lowest values were 0.25, 0.27 mGy and its highest value 0.98, 1.10 mGy respectively. The results showed that the ESD for the majority of the X-ray examinations considered in this study were seen to be higher than those reported in literature. Similarly, the exposure factors (kVp, and mAs) seen to be even higher than those published reports.

Keyword: X-ray, incoming surface dose, exposure, Al Hakeem General Hospital.

1. Introduction

X-rays play an important role in diagnosing many diseases, with serious implications for patients and technicians. They represent the largest artificial source of radiation exposure to the public. When a patient is exposed to a beam of x-rays, some of the photons of these rays pass through the patient's body without any interaction, and this causes vital effects to occur(1). These vital effects always result from excessive exposure to radiation, which in turn causes damage to organs and living tissues, and this damage is uneven due to the variation of tissue sensitivity to different rays. In radiodiagnostic situation, there is an increasing concern about the exposure of patients to large amounts of radiation, and this concern can be seen in the recommendations of the International Committee for Radiological Protection (ICRP)(2-4). All of these studies obligated countries to have the dose given to the patient examined in each x-ray section. Hence there is a need to unify the radiation exposure scale and guidance levels for the various radiological examinations. Radiation dose levels have been proposed by the International Atomic Energy Agency [IAEA] based on British and European studies. Also, a number of international organizations have published several instructions regarding the amount of dose that should be given to the patient, and these instructions have recently led by ICRP to global interest in the amount of dose for patients (5-7). This dose is known as the entrance surface dose (ESD) as it is measured at the center of the x-ray beam and this dose can be estimated by using an optical free dosimeter (TLD) or by using a ionization chamber (IC) or by applying some important mathematical equations in calculating these doses (20-23). The use of a thermal dosimeter TLD in measuring the amount of absorbed dose requires long periods of time and also requires special equipment that may not be available in most x-ray departments, and therefore several mathematical models are proposed that enable the estimation patient dose easily. The first to propose a mathematical equation based on a proposed mathematical model for skin dosimetry is Birtch et al in 1974 (8).In 1984 Edmond published a simple equation for skin dosimetry which depends on kVp, mAs and FSD(9). These mathematical models depend on a number of variables such as the tube voltage (kVp), the distance between the tube and the object (FSD), and the exposure (mAs), which is the product of the tube current multiplied by the exposure time in seconds. On the other hand, the measurement method is based on the ionization chamber (IC) (24-27). The latter may not provide a direct measure of absorbed dose and require mathematical formulas to convert an IC reading into an absorbed dose. Because of the limitations associated with the two methods (IC and TLD), several mathematical models were used to indicate the absorbed dose, exposure factors, the distance between the tube and the body, the filters, and the cross sectional area. Diagnostic radiography that are using charts can be difficult and time consuming (10-12). The main objective of our work is to estimate the entrance surface dose (ESD) for patients in the radiology department of the Al Hakeem General Hospital in Najaf province.

2. Materials and Research Methods

In this research, equation (1) was used to calculate the radiation doses for patients attending the diagnostic radiology department. This research was conducted on 86 patients who access the radiology unit at Al Hakeem General Hospital, and the patient samples included mainly adult women and men. The entrance surface dose (ESD) was estimated using equation [1] for four the radiological examinations, namely arm, wrist, ankle and knee. The equation used in this study was proposed by the two scientists Tang and Tsa in 1999 (7, 13).

$$ESD(mGy) = OP\ [\frac{KV}{80}]^2\ mAs\ [\frac{100}{FSD}]^2\ BSF\ ...(1)$$

Where OP is the tube output per mAs measured at a distance of 100 cm from the tube focus along the beam axis at 80 kVp. KV is the peak of the tube voltage. (kVp) recorded for any given examination (28-31). Where in many cases the output is measured at 80 kVp, and therefore this appears in the equation as a quotient to convert the output into an estimate of that which would be expected at the operational kVp. The value of 80 kVp should be substituted with whatever kVp the actual output is recorded at in any given instance. mAs are the tube current time product which is used in any given instant, FSD is the focus-to-patient entrance surface distance and BSF is the Backscatter factor which is taken to be 1.35 (14, 15, 32-35).

3. Results and Discussion

The entrance surface dose (ESD) of four examinations are common in this hospital, was estimated by using a mathematical equation (1) containing the main exposure factors. Tables 1 to 8 show the amounts of ESD for each of the examinations under study. It can be noted that there is a clear increase in the ESD values when compared with the corresponding ESD values of similar examination. The reason can be attributed to a number of factors that affect the amount of dose. It could be related the non-compliance of technicians to adhere to the correct procedures followed when conducting a radiological process. These procedures are represented in the use of appropriate values for each of the tube voltage (kVp), current (mA), exposure time (Sec), and the patient-to-tube distance (FSD). The current of the tube and exposure time is known as (mAs) and is called exposure. As these factors are what work to increase or decrease radiation doses in the case of radiography. It is known that the voltage of the tube used for radiological examinations changes with the change of the type of examination, where the European Commission (EC) recommends using a voltage ranging from 100 kVp to 120 kVp for adult patients. In this study, we found that the voltage used in the case of the knee (AP) for room No.1 ranged from 50 kVp to 70 kVp with an average of 54.83kVp, while room No.2, it was ranged from 53 kVp to 73 kVp with an average of 56.75kVp. Also, a voltage was used in the case of examining the ankle (AP) in room No. 1, ranging from 50 kVp to 54 kVp, with an average of 52.18 kVp, while room No. 2 had a range from 55 kVp to 59 kVp, with an average of 55.54 kVp. The third examination was for the case of the wrist (AP) in room No.1, ranging from 50 kVp to 58 kVp, with an average of 52.6kVp, while room No. 2 had a range from 50 kVp to 61 kVp, with an average of 55.6kVp.The fourth examination included the condition of the arm (AP) in room No. 1 ranging from 45 kVp to 65 kVp with an average of 52.5 kVp, while room No. 2 had a range from 46 kVp to 70 kVp with an average of 55.4 kVp, respectively. Whereas, the value of the output was 0.06177mGy/mAs for room No. 1, while the value of the output was 0.04611mGy/mAs for room No. 2. As for exposure tube current in time (mAs), the range used in most X-ray examinations ranges from 1.6 mAs to 80 mAs, when comparing the amount of mAs exposure for knee examination to the position (AP) used in this study, it was found to be ranged from 2.4 mA to 13.6 mA. The two chambers are 1,2 with an average amount of 8.48 mA with a previous study conducted in Saudi Arabia in 2015 for the same examination, where the average amount of exposure was 1.6mAs (16) and another study conducted in India in 2015 was the amount of exposure 14mAs (17), and it was also noted that the distance Between the X-ray tube and the patient (FSD) for the same knee examination ranged from 55 cm to 85 cm with an average of 65.83 cm for two rooms 1,2 in the same hospital compared to another study, the mean FSD for the same examination was 71cm.

This significant change in these factors contributes greatly to the increase in the ESD for all tests under this study after comparing them with previous studies and also after comparing them with the international reports (NRPB 2000) (18, 19). Table 9 shows the averages of two of the main factors, kVp and mAs, for all tests, along with the averages of the ESD values for these tests, compared to a study conducted in Saudi Arabia (16) and India (17).

Table (5) shows the exposure factors and the amount of surface dose entering the arm1(AP) examination.				
No.	kVp	FSD	mAs	ESD (mGy)
1	50	93	12.6	0.46
2	45	93	2.4	0.07
3	65	113	2.4	0.10
4	55	63	5	0.48
5	47	73	2.4	0.12
6	55	73	3	0.21
7	60	83	2.4	0.16
8	45	63	3.2	0.20
9	48	73	2.6	0.14
10	55	83	5	0.28
Average	52.5	81	4.1	0.22
SD	6.67	15.49	3.16	0.14
MIN	45	63	2.4	0.07
MAX	65	113	12.6	0.48

Table (6) shows the exposure factors and the amount of surface dose entering the wrist1(AP) examination.				
No.	kVp	FSD	mAs	ESD (mGy)
1	50	95	12.6	0.44
2	58	65	5	0.50
3	53	65	5	0.42
4	50	65	12.6	0.94
5	55	65	12.6	1.13
6	50	75	12	0.67
7	53	75	4	0.25
8	54	75	5	0.33
9	52	65	6	0.48
10	51	65	5	0.37
Average	52.6	71	7.98	0.55
SD	2.59	9.66	3.88	0.28
MIN	50	65	4	0.25
MAX	58	95	12.6	0.94

Table (7) shows the exposure factors and the amount of surface dose entering the ankle1/AP examination.				
No.	kVp	FSD	mAs	ESD (mGy)
1	50	90	7.2	0.28
2	53	70	5	0.36
3	53	70	4	0.29
4	53	70	5	0.36
5	52	70	4	0.28
6	50	70	6	0.38
7	51	70	5	0.33
8	55	70	6	0.46
9	53	70	5	0.36
10	50	70	4	0.26
11	54	70	6.2	0.46
Average	52.18	71.82	5.22	0.35
SD	1.72	6.03	1.04	0.07
MIN	50	70	4	0.26
MAX	55	90	7.2	0.46

Table (8) shows the exposure factors and the amount of surface dose entering the knee1(AP) examination.				
No.	kVp	FSD	mAs	ESD (mGy)
1	70	85	11.52	0.98
2	55	65	2.8	0.25
3	50	65	4	0.30
4	55	65	5	0.45
5	60	65	5	0.53
6	50	65	3.6	0.27
7	50	65	4	0.30
8	53	55	5	0.58
9	55	65	4	0.36
10	60	75	5	0.40
11	50	55	5.6	0.58
12	50	65	5	0.37
Average	54.83	54.29	5.04	0.41
SD	6.06	23.67	2.19	0.25
MIN	50	55	2.8	0.25
MAX	70	85	11.52	0.98

Table (1) shows the exposure factors and the amount of surface dose entering the arm2(AP) examination.

No.	kVp	FSD	mAs	ESD (mGy)
1	52	93	13.2	0.39
2	47	93	2.4	0.06
3	70	113	3.2	0.12
4	56	63	6	0.44
5	52	73	3	0.14
6	57	73	3.4	0.19
7	64	83	2.4	0.13
8	46	63	3.6	0.18
9	53	73	2.8	0.14
10	57	83	5.2	0.23
Average	55.4	81	4.52	0.20
SD	7.31	15.49	3.27	0.12
MIN	46	63	2.4	0.06
MAX	70	113	13.2	0.44

Table (2) shows the exposure factors and the amount of surface dose entering the wrist2(AP) examination.

No.	kVp	FSD	mAs	ESD (mGy)
1	50	95	12.8	0.44
2	61	65	5.6	0.62
3	57	65	5.4	0.52
4	55	65	13.6	1.22
5	60	65	13.4	1.43
6	54	75	12.6	0.82
7	55	75	4.6	0.31
8	56	75	5	0.35
9	57	65	6.6	0.64
10	51	65	5.2	0.40
Average	55.6	71	8.48	0.68
SD	3.47	9.66	4.02	0.38
MIN	50	65	4.6	0.31
MAX	61	95	13.6	1.43

Table (3) shows the exposure factors and the amount of surface dose entering the ankle2(AP) examination.

No.	kVp	FSD	mAs	ESD (mGy)
1	55	90	7.2	0.34
2	58	70	5	0.43
3	55	70	4	0.31
4	58	70	5	0.43
5	53	70	4	0.29
6	51	70	6	0.40
7	53	70	5	0.36
8	58	70	6	0.52
9	56	70	5	0.40
10	55	70	4	0.30
11	59	70	6.2	0.55
Average	55.55	71.82	5.22	0.39
SD	2.54	6.03	1.04	0.09
MIN	51	70	4	0.29
MAX	59	90	7.2	0.55

Table (4) shows the exposure factors and the amount of surface dose entering the knee2(AP) examination.

No.	kVp	FSD	mAs	ESD (mGy)
1	73	85	11.84	1.10
2	55	65	3	0.27
3	50	65	4.4	0.33
4	57	65	5.4	0.52
5	64	65	5.2	0.63
6	52	65	4.4	0.35
7	51	65	4.8	0.37
8	58	55	6	0.84
9	56	65	4.2	0.39
10	62	75	5.8	0.50
11	50	55	6	0.62
12	53	65	6	0.50
Average	56.75	65.83	5.59	0.53
SD	6.81	7.93	2.17	0.24
MIN	50	55	3	0.27
MAX	73	85	11.84	1.10

Table 9: Comparison average values of ESD, FSD, mAs and kVp with other Studies.

Examination type	Current study			Saudi Arabia(16)			India(17)		
	kVp	mAs	ESD	kVp	mAs	ESD	kVp	mAs	ESD
Arm (AP)	53.95	4.31	0.21	-	-	-	-	-	-
Wrist (AP)	54.1	8.23	0.61	-	-	-	49	8	0.13
Ankle (AP)	53.86	5.21	0.37	-	-	-	51	11	0.17
Knee (AP)	55.80	5.28	0.47	48.9	1.61	0.04	54	14	0.22

4. Conclusions

The results of the study show that with the increase of the tube voltage (kVp) and the tube loading (mAs), the amount of surface dose increases, and thus the amount of dose absorbed by the body organs increases. Also the increase in the distance between the tube and the patient (FSD) leads to a decrease in the amount of incoming dose, and this is consistent with the inverse square law.

When comparing these results with what is found in the journals and some available studies, we found that there is a slight increase in the amount of entrance surface dose (ESD). This may be due to several reasons, including non-application of quality standards for the devices used in the considered hospital. It can also be related to accuracy of the voltage, the compatibility of the tube current, the adjustment of the exposure beam and the distance between the tube and the patient.

The most comprehensive conclusion in this research is that there should be a quality assurance and monitoring program in order to reach a reduction in radiation doses for patients and workers in hospital radiology departments, and that there should be workshops for technicians to clarify the risks of increasing radiation doses as well as work to determine local reference levels for radiation doses.

References

1. Mraity HA, England A, Hogg P. Gonad dose in AP pelvis radiography: impact of anode heel orientation. Radiography. 2017;23(1):14-8.
2. Valentin J. Avoidance of radiation injuries from medical interventional procedures, ICRP Publication 85. Annals of the ICRP. 2000;30(2):7-.
3. Davies ER. Quality Assurance in Diagnostic Radiology, World Health Organisation, Eastbourne (1982) Quality Assurance in Nuclear Medicine, World Health Organisation, Switzerland (1982), 70 pp. WB Saunders; 1983.
4. Al-Ghamdi S, Al-Garawi M, Al-Habeeb S, Outif A, Abdelhalim M. The formulation of local diagnostic reference levels for several diagnostic X-ray examinations at Security Forces Hospital in Riyadh (A survey for the doses received by patients undergoing diagnostic X-ray at Security Forces Hospital in Riyadh and identifying the factors required for lowering the patient doses). Journal of American Science. 2013;9(9s).
5. Landberg T, Chavaudra J, Dobbs J, Gerard J-P, Hanks G, Horiot J-C, et al. ICRU reports. Reports of the International Commission on Radiation Units and Measurements. 1999(1):48-51.
6. White D, Griffith R, Wilson I. ICRU reports. Reports of the International Commission on Radiation Units and Measurements. 1992(1):203-5.
7. Ali Rmkm, Mraity HAAB. Estimation of Radiation Dose from Most Common Pediatrics Radiographic Examinations within Main Central Hospitals in Najaf City, Iraq. Baghdad Science Journal. 2022;19(3):0654-.
8. Birch R, Marshall M. Computation of bremsstrahlung x-ray spectra and comparison with spectra measured with a Ge (Li) detector. Physics in Medicine & Biology. 1979;24(3):505.
9. Edmonds I. Calculation of patient skin dose from diagnostic X-ray procedures. The British journal of radiology. 1984;57(680):733-4.
10. Cardillo I, Boal T, Einsiedel P. Patient doses from chest radiography in Victoria. Australasian Physical & Engineering Sciences in Medicine. 1997;20(2):92-101.
11. Cardillo I, Boal T, Hedt J. A survey of radiation doses to adults from diagnostic radiology in Victoria. Australasian Physical & Engineering Sciences in Medicine. 1999;22(2):64-72.
12. Li L, Wang J, Yu X, He S, Yu F, Ding C. Medical radiation usage and exposures from medical X ray diagnosis in Shandong province of China. Radiation protection dosimetry. 2001;93(3):261-6.
13. Tung C-J, Tsai H-Y. Evaluations of gonad and fetal doses for diagnostic radiology. PROCEEDINGS-NATIONAL SCIENCE COUNCIL REPUBLIC OF CHINA PART B LIFE SCIENCES. 1999;23:107-13.
14. Kuppusamy T. Basic radiological physics: JP Medical Ltd; 2017.
15. Yadav L, Boora N, Kumar R, Sah NK. Assessment of Knowledge of Radiographic Students about Radiation Protection Devices, Their Use and Handling.
16. Akhdar HF. Assessment of Entrance Skin Dose and Effective Dose of Some Routine X-ray Examinations Using Calculation Technique. KSU (M Sc thesis). 2007.
17. Sharma R, Sharma SD, Pawar S, Chaubey A, Kantharia S, Babu D. Radiation dose to patients from X-ray radiographic examinations using computed radiography imaging system. Journal of Medical Physics/Association of Medical Physicists of India. 2015;40(1):29.
18. Hart D, Hillier M, Wall B. National reference doses for common radiographic, fluoroscopic and dental X-ray examinations in the UK. The British journal of radiology. 2009;82(973):1-12.
19. Hart D, Wall B. The UK national patient dose database: now and in the future. The british journal

of radiology. 2003;76(906):361-5.
20. Narayan, Vipul, and A. K. Daniel. "Design consideration and issues in wireless sensor network deployment." (2020): 101-109.
21. Choudhary, Shubham, et al. "Fuzzy approach-based stable energy-efficient AODV routing protocol in mobile ad hoc networks." Software Defined Networking for Ad Hoc Networks. Cham: Springer International Publishing, 2022. 125-139.
22. Narayan, Vipul, and A. K. Daniel. "RBCHS: Region-based cluster head selection protocol in wireless sensor network." Proceedings of Integrated Intelligence Enable Networks and Computing: IIENC 2020. Springer Singapore, 2021.
23. Narayan, Vipul, and A. K. Daniel. "CHOP: Maximum coverage optimization and resolve hole healing problem using sleep and wake-up technique for WSN." ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal 11.2 (2022): 159-178.
24. Narayan, Vipul, and A. K. Daniel. "CHHP: coverage optimization and hole healing protocol using sleep and wake-up concept for wireless sensor network." International Journal of System Assurance Engineering and Management 13.Suppl 1 (2022): 546-556.
25. Narayan, Vipul, and A. K. Daniel. "IOT based sensor monitoring system for smart complex and shopping malls." Mobile Networks and Management: 11th EAI International Conference, MONAMI 2021, Virtual Event, October 27-29, 2021, Proceedings. Cham: Springer International Publishing, 2022.
26. Narayan, Vipul, and A. K. Daniel. "Energy Efficient Protocol for Lifetime Prediction of Wireless Sensor Network using Multivariate Polynomial Regression Model." Journal of Scientific & Industrial Research 81.12 (2022): 1297-1309.
27. Awasthi, Shashank, et al. "A Comparative Study of Various CAPTCHA Methods for Securing Web Pages." 2019 International Conference on Automation, Computational and Technology Management (ICACTM). IEEE, 2019.
28. Narayan, Vipul, and A. K. Daniel. "FBCHS: Fuzzy Based Cluster Head Selection Protocol to Enhance Network Lifetime of WSN." ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal 11.3 (2022): 285-307.
29. Narayan, Vipul, et al. "E-Commerce recommendation method based on collaborative filtering technology." International Journal of Current Engineering and Technology 7.3 (2017): 974-982.
30. Narayan, Vipul, et al. "To Implement a Web Page using Thread in Java." (2017).
31. Srivastava, Swapnita, and P. K. Singh. "HCIP: Hybrid Short Long History Table-based Cache Instruction Prefetcher." International Journal of Next-Generation Computing 13.3 (2022).
32. Srivastava, Swapnita, and P. K. Singh. "Proof of Optimality based on Greedy Algorithm for Offline Cache Replacement Algorithm." International Journal of Next-Generation Computing 13.3 (2022).
33. Smiti, Puja, Swapnita Srivastava, and Nitin Rakesh. "Video and audio streaming issues in multimedia application." 2018 8th International Conference on Cloud Computing, Data Science & Engineering (Confluence). IEEE, 2018.
34. Srivastava, Swapnita, and Shilpi Sharma. "Analysis of cyber related issues by implementing data mining Algorithm." 2019 9th International Conference on Cloud Computing, Data Science & Engineering (Confluence). IEEE, 2019.
35. Narayan, Vipul, and A. K. Daniel. "Multi-tier cluster based smart farming using wireless sensor network." 2020 5th international conference on computing, communication and security (ICCCS). IEEE, 2020