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Assessment of Entrance Skin Dose of X-ray Using Calculation Techniques.

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Abstract- skin dose estimation is usefull and well established method for quality control in diagonostic radiology and provide valuable information about the efficacy of the department. This study assessed. skin dose estimation using Mathematical Formula at Yobe State University Teaching Hospital Damaturu, Yobe State Nigeria. The main objective of the study was to calculate entrance skin dose of X-ray using Mathematical formula and to compare the result with the same measured dose using survey meter to test the percentage accuracy of the formula. The study employed the use of prospective research method. 50 patient's datas were analysed and their ESD is obtained both mathematically and physically using survey meter and the two results are in good positive correlation using inferential statistical tools, these confirmed the accuracy of the formulas. Findings of the study revealed that out of three formulas used to calculate ESD (Chan & Tsai, Edmond and Kumar) the Kumar method has the strongest positive correlation with the survey meter value in a very close range results. The result further showed that the high population to receive the dose during x-ray examination are obese due to the increase in exposure factor (kVp & mAs) in a high body thickness liable of high attenuation capacity than the small body thickness. Furthermore the contributing factor involved in dose deposition in patients is the faults of the radiation workers dissipating x-ray, (x-ray technician and radiographers) due to the misuse of the machine parameters (exposure factors) and machine manipulation(misuse of beam limiting and centering devices protecting scatter, collimators delineation and beam diaphragm) misuse of anti-scatter grid, etc. The study recommends the training and re-training of radiographers should be focused on, so that issue of dose deposition in patients will be minimized.

Indexed Terms- skin dose, formula, x-ray.

I. INTRODUCTION

Medical imaging plays a crucial role in modern healthcare, with X-ray examinations being one of the most commonly used diagnostic tools. While X-rays provide valuable insights for disease diagnosis and treatment planning, their ionizing nature raises concerns about radiation exposure and associated risks. Ensuring patient safety during radiographic procedures requires a careful balance between obtaining high-quality diagnostic images and minimizing radiation dose.

One of the key parameters used to assess radiation exposure in diagnostic radiology is the Entrance Skin Dose (ESD)—the amount of radiation absorbed by a patient's skin at the point of entry. The accurate estimation of ESD is vital for evaluating radiation risks, optimizing imaging protocols, and ensuring compliance with radiation protection guidelines. Several techniques exist for determining ESD, including direct measurements using dosimeters and indirect estimation through computational methods.

This study focuses on the assessment of ESD using calculation techniques, which provide a cost-effective and practical alternative to direct measurement. These techniques involve the use of standard dose equations, exposure parameters (such as tube voltage, tube current, and exposure time), patient-specific factors, and established radiation conversion coefficients. By applying these methods, it is possible to estimate ESD with reasonable accuracy and contribute to dose optimization in radiographic procedures.

The objective of this research is to evaluate and validate computational approaches for estimating ESD in diagnostic X-ray examinations. The findings will help enhance radiation safety practices, promote adherence to radiation protection standards, and guide medical practitioners in optimizing X-ray exposure parameters to minimize unnecessary radiation exposure while maintaining diagnostic efficacy.

II. RESEARCH GAPS

1. Lack of Standardized Calculation Models for ESD Assessment

Different calculation techniques (e.g., direct exposure parameters, Monte Carlo simulations, Dosimetric equations) yield varying results, and there is no universally accepted standard.

Existing models do not account for patient-specific variations, such as skin thickness and tissue composition, leading to inconsistencies.

2. Limited Validation with Measured Dose Values

Many studies rely solely on theoretical calculations without experimental validation using thermoluminescent dosimeters (TLDs) or ionization chambers.

The correlation between calculated and measured ESD values remains underexplored, particularly in resource-limited settings.

3. Insufficient Data on Pediatric and Geriatric Populations

Most studies focus on adult patients, neglecting pediatric and elderly populations who may have different radiation absorption characteristics.

Dose estimation techniques are not always optimized for these vulnerable groups, leading to potential underestimation or overestimation of risks.

4. Variability in X-ray Machine Parameters and Protocols

Differences in tube voltage (kVp), tube current (mAs), and filtration systems significantly impact ESD, yet standardization is lacking across different hospitals.

Many studies do not consider variations in X-ray machine calibration, leading to inconsisten estimations.

III. RECENT ADVANCEMENT IN ENTRANCE SKIN DOSE ASSESSMENT

1. Utilization of Optically Stimulated Luminescence Dosimeters (OSLDs): OSLDs, such as nanoDots, have emerged as reliable tools for measuring ESD. A study demonstrated their feasibility in determining average glandular dose (AGD) in digital breast tomosynthesis (DBT) systems, showing variations within ±5% compared to ionization chambers. This suggests that OSLDs can serve as practical alternatives for AGD assessment in both 2D and 3D imaging modes.

2. Monte Carlo Simulation Techniques: Advanced Monte Carlo (MC) simulations have been employed to estimate organ doses from measured ESD values. For instance, a study utilized MC methods to calculate organ doses in pediatric chest radiography, providing conversion coefficients to translate ESD into specific organ doses. This approach enhances the accuracy of

dose estimation, particularly in vulnerable populations.

3. Development of Fast Dose Estimation Systems: Innovative systems like the Fast Dose Estimation in Interventional Radiology (FDEIR) leverage GPU-based Monte Carlo simulations to provide rapid skin dose estimations during interventional procedures. By utilizing patient-specific CT data and fluoroscopic conditions, FDEIR offers real-time dose assessments, improving patient safety and procedure optimization.

4. High-Resolution Surface Dosimetry in MR-Linac Systems: The integration of Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) detectors, such as MOSkin™, has enabled high-resolution dosimetry in magnetic resonance-guided linear accelerator (MR-linac) systems. These detectors provide accurate skin dose measurements at beam entry and exit points, crucial for treatments involving steep dose gradients.

5. Comparative Studies of ESD Estimation Methods: Recent research has compared direct and indirect methods of estimating ESD across various diagnostic radiation qualities using water phantoms and shadow.

The Need for Accuracy in ESD Assessment

Accurate assessment of Entrance Skin Dose (ESD) is essential for several reasons, particularly in the field of diagnostic radiology and radiation protection. Some of the key needs for accuracy in ESD estimation include:

1. Patient Safety and Radiation Protection

- Overexposure to ionizing radiation increases the risk of stochastic effects (such as cancer) and deterministic effects (such as skin injuries).
- Accurate ESD estimation helps ensure that patients receive the lowest possible dose while obtaining high-quality diagnostic images.

2. Compliance with Radiation Safety Regulations

- National and international radiation protection bodies, such as the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), set guidelines for radiation dose limits.
- Precise ESD calculations help healthcare facilities comply with these standards and avoid unnecessary exposure.

3. Optimization of Imaging Techniques

- Accurate ESD estimation allows radiographers to fine-tune imaging parameters (kVp, mAs, filtration, and source-to-skin distance) to reduce radiation dose without compromising image quality.
- This contributes to the principle of ALARA (As Low As Reasonably Achievable) in radiation protection.

4. Quality Assurance and Equipment Calibration

- Regular assessment of ESD ensures that X-ray machines are functioning correctly and delivering expected doses.
- Inaccurate dose estimations may indicate issues such as improper calibration, tube aging, or faulty exposure settings.

5. Dosimetry and Risk Assessment

- Estimating ESD accurately allows for better dosimetry calculations, which are essential for evaluating long-term radiation exposure risks.

- It also helps in epidemiological studies investigating the health effects of radiation exposure.

6. Consistency in Medical and Research Applications

- Accurate ESD calculations contribute to standardization in medical imaging, ensuring consistent dose levels across different hospitals and imaging centers.
- Researchers can rely on precise ESD data for comparative studies and dose optimization strategies.

IV. MATERIALS AND METHODS

Study Area

This study was conducted at Yobe State Teaching Hospital, Damaturu, Yobe State, Nigeria, a major healthcare facility that provides diagnostic imaging services to a wide range of patients. The hospital is equipped with modern radiographic equipment used for various X-ray examinations, making it a suitable location for assessing Entrance Skin Dose (ESD) using computational techniques.

Study Design

A quantitative approach was employed to estimate the Entrance Skin Dose (ESD) for patients undergoing X-ray examinations. The study involved data collection from selected radiographic procedures and subsequent ESD calculations using standard computational techniques.

Equipment and Materials

The following materials and instruments were used in the study:

1. Survey Meter

- A calibrated radiation survey meter was used to measure radiation output from the X-ray machine.
- The meter was positioned at an appropriate distance to determine the air kerma (radiation dose in air) as part of the dose estimation process.

2. Data Capture Sheet

A structured data capture sheet was designed to record essential parameters for each X-ray examination, including:

- Tube voltage (kVp)
- Tube current-time product (mAs)
- Source-to-skin distance (SSD)
- Filtration settings
- Patient demographic information (age, weight, and height)
- X-ray projection and body part examined
- The recorded data was used to perform entrance skin dose calculations.

Data Collection Procedure

1. Measurement of X-ray Output

- The survey meter was used to determine the output of the X-ray machine in terms of air kerma at a known distance.
- This measurement was essential for calculating ESD using conversion factors.

2. Patient Data Collection

- Patients undergoing routine X-ray examinations were selected for the study.
- Ethical approval and informed consent were obtained before recording patient data.

- The data capture sheet was used to document exposure parameters and other relevant details.

V. RESULT PRESENTATION

The anthropometric characteristics of the patient's information's such as age, weight and height and technical parameters such ask Vp,m As and the distance from the Xray machine to the skin of the patient's(focus to skin distance(FSD))were entered into a capture sheet for each type of examinations. The mean values of patient information and technical parameters were calculated and was presented in Table 4.2.50 patients were examined and both male and female were examined. The mean values of the age of the patients were ranges from 0 – 10 years, 11– 20 years and 21 – 30 years 31 - 40 years 41 – 50 years 51 – 60 years, with their subsequent height and weight measured respectively. The mean technical parameters values:kVp,m As and FSD were selected according to the patient age and weight.

The data obtained from patient's information and technical parameters in Table 4.1 were used to calculate ESD (mGy) using three formulas: (Chan & Tsai, 1999; Edmond 1989; Kumar et al., 1996) formulas and are presented in Table 4.2 below:

Table 4.1: Data Sheet

S/N	Age (years)	Weight (kg)	Height (m)	Diagnostic/View	kVp	mAs	FSD (cm)	Survey Meter (mGy)
1	58	75	1.82	CXR AP	70	10	100	0.4064
2	58	67	1.65	CXR AP	70	10	100	0.4064
3	58	73	1.72	Shoulder AP	72	12	100	0.5115
4	30	55	1.24	Shoulder AP	68	10	100	0.3815
5	30	63	1.26	Shoulder AP	68	10	100	0.3815
6	60	78	1.82	CXR PA	78	16	100	0.4758
7	54	68	1.78	Cervical AP	76	16	120	0.353
8	54	68	1.80	Cervical AP	76	16	120	0.333
9	54	70	1.64	Thoracic AP	96	32	120	1.7453
10	54	74	1.72	Thoracic AP	96	32	120	1.7453
11	53	72	1.76	CXR PA	76	20	150	0.4258
12	58	75	1.92	L/S Lat	95	20	180	1.4981
13	18	38	0.70	Knee AP	60	3.20	90	0.1082
14	18	35	0.76	Knee Lat	60	3.20	90	0.1082
15	45	60	1.32	L/S AP	100	40	100	3.4323
16	45	65	1.42	L/S Lat	115	46	100	5.3652
17	52	68	1.68	Knee AP	60	3.20	90	0.1082
18	52	72	1.69	Knee Lat	60	3.20	90	0.1082
19	30	62	1.24	Knee AP	65	5.0	90	0.2150
20	30	58	1.34	Knee Lat	65	5.0	90	0.2150
21	07	18	0.35	CXR PA	56	4.0	100	0.1039
22	03	37	0.17	CXR PA	53	3.2	100	0.0737
23	03	36	0.20	CXR Lat	58	3.0	80	0.1547

S/N	Age (years)	Weight (kg)	Height (m)	Diagnostic/View	kVp	mAs	FSD (cm)	Survey Meter (mGy)
24	01.1	5	0.10	CXR AP	58	3.0	80	0.1647
25	01.1	8	0.11	CXR Lat	53	3.0	80	0.0700
26	52	78	1.67	Knee AP	58	3.2	90	0.1077
27	52	75	1.82	Knee Lat	58	3.2	90	0.1077
28	48	68	1.65	Knee AP	65	5.0	90	0.2150
29	48	70	1.63	Knee Lat	65	5.0	90	0.2150
30	39	65	1.46	Mastoid RLO	48	12.0	100	0.2316
31	39	68	1.48	Mastoid LLO	56	16.0	100	0.2316
32	18	25	0.76	Mastoid AO	76	16.0	100	0.4156
33	18	25	0.76	ThrcL AP	76	16.0	100	0.7666
34	18	28	0.74	ThrcL Lat	76	16.0	100	0.7666
35	23	32	0.86	Legs AP	80	16.0	120	0.5857
36	23	30	0.90	Legs Lat	80	16.0	120	0.5857
37	35	67	1.10	CXR PA	75	16.0	120	0.4171
38	35	68	1.20	CXR AP	75	16.0	120	0.4171
39	32	58	1.15	CXR AP	74	12.0	120	0.3778
40	32	60	1.18	CXR PA	74	12.0	120	0.3778
41	18	24	0.80	CXR PA	52	3.2	120	0.0488
42	40	60	1.40	Lumbar Lat	95	40	120	2.1393
43	40	75	4.42	Lumbar AP	100	40	150	1.4977
44	28	55	1.02	Lumbar AP	120	20	150	1.8231
45	28	55	1.03	Lumbar AP	80	20	150	0.4733
46	40	75	1.50	Pelvis AP	68	20	150	0.3394
47	40	72	1.45	Pelvis AP	68	10	150	0.1699
48	18	35	0.80	Hand AP	55	10	80	0.2946
49	18	32	0.84	Hand Lat	55	2.5	80	0.1341
50	30	58	1.08	Lumbar AP	85	12	120	0.5049

Table: 4.2 Frequency Distribution Table

S/N	Age Interval	Frequency	Percentage (%)
1	0 - 10	5	10
2	11 - 20	7	14
3	21 - 30	9	18
4	31 - 40	11	22
5	41 - 50	4	8
6	51 - 60	14	28
	Total	50	100

From the table above the result shows that the age and sex interval that had the highest occurrence are between age and sex range of 51- 60 which constitute the percentage of 14 (28%) respectively while those that had the age and sex interval (41-50) had the lowest occurrence which constitute the frequency and percentage of 4 (8%) respectively.

Table 4.3: Result showing the result obtained from the formulas with the measured value from a survey meter.

S/No.	Diagnostic Type	Chan & Tsai Method (mGy)	Edmond Method (mGy)	Kumar Method (mGy)	Survey Meter Value (mSv)
1	CXAP	0.5493	0.2608	0.4090	0.4064
2	CXAP	0.5493	0.2608	0.4090	0.4064
3	Shoulder AP	0.6905	0.3129	0.5310	0.5115
4	Shoulder AP	0.5132	0.2533	0.3780	0.3815
5	Shoulder AP	0.5132	0.2533	0.3780	0.3815
6	CXR PA	1.0805	0.4649	0.8820	0.4758
7	Cervical AP	0.7123	0.3146	0.3700	0.3530
8	Cervical AP	0.7123	0.3146	0.5700	0.3330
9	Thoracic AP	2.2732	0.7948	2.1680	1.7453
10	Thoracic AP	2.2732	0.7948	2.1680	1.7453
11	CXR PA	0.5698	0.2517	0.4560	0.4258
12	L/S Lat	0.3182	0.2184	3.6578	1.4981
13	Knee AP	0.1405	0.0780	0.1060	0.1082
14	Knee Lat	0.1405	0.0780	0.1060	0.1082
15	L/S AP	4.4400	1.1400	4.3670	3.4323
16	L/S Lat	6.7526	1.9690	7.3740	5.3652
17	Knee AP	0.1405	0.0780	0.1060	0.1082
18	Knee Lat	0.1405	0.0780	0.1060	0.1082
19	Knee AP	0.2894	0.1495	0.2060	0.2150
20	Knee Lat	0.2894	0.1695	0.2060	0.2150
21	CXR PA	0.1392	0.0834	0.0890	0.1039
22	CXR PA	0.0997	0.0632	0.0610	0.0737
23	CXR Lat	0.1760	0.1742	0.1140	0.1547
24	CXR AP	0.1760	0.1742	0.1140	0.1647
25	CXR Lat	0.0940	0.0594	0.0570	0.0700
26	Knee AP	0.1470	0.0800	0.0960	0.1077
27	Knee Lat	0.1470	0.0800	0.0960	0.1077
28	Knee AP	0.2894	0.1495	0.2060	0.2150
29	Knee Lat	0.2894	0.1495	0.2060	0.2150
30	Mastoid RLO	0.3060	0.2147	0.1740	0.2316
31	Mastoid LLO	0.3060	0.2147	0.1740	0.2316
32	Mastoid AO	0.5580	0.3380	0.3550	0.4156
33	Thoracic AP	1.0260	0.4530	0.8210	0.7666

S/No.	Diagnostic Type	Chan & Tsai Method (mGy)	Edmond Method (mGy)	Kumar Method (mGy)	Survey Meter Value (mSv)
34	Thoracic Lat	1.0260	0.4530	0.8210	0.7666
35	Legs AP	0.7890	0.3311	0.6570	0.5857
36	Legs Lat	0.7890	0.3311	0.6570	0.5857
37	CXR PA	0.3910	0.3104	0.5500	0.4171
38	CXR AP	0.3910	0.3104	0.5500	0.4171
39	CXR AP	0.5060	0.2293	0.3980	0.3778
40	CXR PA	0.5060	0.2293	0.3980	0.3778
41	CXR PA	0.0660	0.0404	0.0040	0.0488
42	Lumbar Lat	2.7840	1.0000	2.6340	2.1393
43	Lumbar AP	1.9710	0.5812	1.9410	1.4977
44	Lumbar AP	3.4700	0.3974	1.6020	1.8231
45	Lumbar AP	0.6300	0.2649	0.5250	0.4733
46	Pelvis AP	0.4570	0.2252	0.3360	0.3394
47	Pelvis AP	0.2290	0.1126	0.1680	0.1699
48	Hand AP	0.5250	0.0290	0.3300	0.2946
49	Hand Lat	0.3130	0.0073	0.0820	0.1341
50	Lumbar AP	0.6690	0.2639	0.5820	0.5049

DISCUSION

From all the literature review, it has been found that the most accurate among the formulas used in this study was Kumar formula, and this also in agreement with the result obtained from this work, although the remaining ones are also in close range with the survey meter value with slight difference of 0.3 in between each. Also From the table 4.2 above; the result shows that the age and sex interval that had the highest occurrence are between age range of 51- 60 which constitute the percentage of 14 (28%) respectively while those that had the age interval (41-50) had the lowest occurrence which constitute the frequency and percentage of 4 (8%) respectively, these shows that; obese people received high dose and are liable to have high dose deposition in their body tissue due to increase in exposure factors because of the density of their body, hence; the denser the tissue the higher the attenuation and the higher the dose deposition.

SUMMARY

The entrance skin dose and effective dose have been estimated using indirect methods (computation using technique factors and machine parameters) employing three different formulas proposed by various authors in the field and was compared with surveys in the case study values (YSUTH). The radiation dose to the patients is dependent of mAs, output of X-ray machines kVp, filtration, focus-skin distance. Though the use of the indirect method of radiation measurement is a realistic alternative to the use of TLD and survey meter, it is important to use the appropriate formula that includes all the factors that contribute to the dose of the patient.

This enhances the determination of true value of the dose delivered to the patient during radio graphic examinations, and hence, the risks involved.

A total number of 50 patients were examine at YSUTH Damaturu. In this survey, biographical data such as patient age, weight, height and machine parameters were recorded. The mean calculated ESD values for Chan & Tsai, Edmond, and Kumar formulas were found to be in close range with each other with the variation based on selected factors according to the patient size and age. Hence, the denser the object the higher the dose.

CONCLUSION

Dose monitoring helps to ensure that the best possible protection of the patient is maintained at all times and provides an immediate indication of incorrect use of technical parameters or equipment malfunction. During diagnostic X-ray, the kVp and mAs are very important parameters which controls the quality of X-ray picture.

RECOMMENDATIONS

Due to the universally and high percentage of routine X-rays requests to the radiology department such as conventional X-rays, skull, and extremities as obtained in the data sheet and the important role of this test in patient's cumulative doses, specific strategist must be performed to reduce patient dose in this test.

5.4.1 The ALARA (As Low as Reasonable Achievable) principle should be used when carrying out X-ray activities.

5.4.2 Trainingofpersonalandconsistencyinqualityassurance programwillgoalongway in reducing the radiation doses received by the patients.

5.4.3 Further study are required in other radiographic centers within Damaturu in order to optimize radiation dose and establish local diagnostic reference level (DRL). 5.4.4 Estimation of entrances kin dose for patients undergoing Computed Tomography (CT).

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