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Assessment of patient entrance surface and effective dose in the skull and thoraco-lumbar X-ray examinations

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ABSTRACT

Purpose: The review effort throughout the states was needed by the major concern of increased risk of cancer due to radiation exposure in patients during routine X-ray. This study aims to assess the patient entrance surface dosage during X-ray examinations of the skull and thoraco-lumbar spine.

Materials and methods: Using a CALDOSE software tool, the dosage received by 146 individuals was assessed based on many technical criteria, including the source-to-image receptor distance, photon quantity by mill ampere second, and photon energy by kilo volt peak.

Results: The average entrance surface air kerma (ESAK) is 0.52 for the skull and 0.77 for the thoracic spine. The typical value of the incident air kerma (INAK) is 0.47 for the skull and 0.58 for the thoracic lumbar region.

Conclusions: ESAK and INAK are quite effective for comparing the thoracic spine to the cranium. ESAK and INAK can offer data on dosage reduction that should be utilized in the optimization of skull and thoraco-lumbar X-ray examinations.

Keywords: X-ray, dose, ESAK, INAK, skull, thoraco-lumbar, examinations

INTRODUCTION

Regularly, a multitude of X-ray machines are employed in the fields of medical and industry for the purpose of conducting examinations, inspections, and process controls. The radiation doses generated by X-ray exams vary based on the imaging technologies and exposure settings used. Given the substantial global volume of X-ray exams undertaken annually, X-ray imaging significantly accounts for the highest proportion of population dosage [1]. X-rays are the most prevalent type of artificial radiation exposure due to their wide range of uses. Diagnostic X-ray is a commonly employed imaging technique for identifying pathological conditions in both children and adults. Nevertheless, X-rays include intrinsic hazards that are particularly worrisome when employed on young infants [2]. Radiation poses a substantial risk in the context of diagnostic and therapeutic medical imaging. Fluctuations in the parameters mill ampere second (mAs) and kilo volt peak (kVp), along with variations in patients' technological habits, might lead to issues in dose levels [3].

The primary factors contributing to the rising utilization of radiological investigations include advancements in radiological technology, growing demand from individuals, clinicians' low tolerance for uncertainty, expanded clinical indications, and improved accessibility [4]. This prevalence was enhanced by implementing a quality control (QC) methodology that guarantees a sharp image and minimal radiation exposure to the patient. Effective optimization in medical exposures involves minimizing the radiation dose to the lowest practical level while maintaining sufficient image quality for diagnostic purposes. Regrettably, several government and private hospitals, as well as community health facilities, currently neglect the QC criteria. This lack of knowledge is consistently rationalized by the presence of advanced digital X-ray machines and/or the absence of inspection equipment and trained workers. Consequently, the standards and training of the specialist staff were disregarded [5].

During radiological examinations, patients are exposed to radiation dosages that are essential for mitigating the hazards of exposure that could affect a large number of individuals. The estimation of cancer and genetic consequences caused by radiation can be conducted utilizing a range of indicators. According to the international commission on radiological protection, the effective dose (ED) is considered the primary

Table 1. Patient's data and scan parameters

Parameter	Minimum	Maximum	Mean	Standard deviation
Age	18	75	42.47	13.9
Height (cm)	148	189	168.4	8.1
Weight (kg)	54	112	76.2	10.8
kVp (skull)	65	75	68.0	5.0
kVp (thoracic)	70	90	76.0	5.0
mAs (skull)	9	15	12.0	3.0
mAs (thoracic)	25	55	43.0	4.0

and essential measure in the field of radiological patient protection as it directly correlates with the potential harm to health [6, 7]. Accurate assessment of ED is crucial as it is influenced by both patient anatomy and radiological technique. As the measurement of ED is not feasible directly in clinical procedures, it must be assessed indirectly. Typically, the effective dosage generated from the incident air kerma (INAK) measurements is indirectly assessed [8, 9]. The population in the Red Sea State has grown, leading to a higher frequency of traditional X-ray exams. However, patient dose recording and picture QC in medical X-ray examinations are not considered at Red Sea facilities. This study aims to evaluate the patient entrance surface dose and effective dosage may lack in a QC program or established processes.

MATERIALS AND METHODS

Four X-ray machines in four major government hospitals were included. These X-ray machines are Shimadzu Kyoto-Japan. X-ray exposure parameters such as kVp, mill ampere, mAs, and focus skin-distance were immediately recorded from each patient's and projection's control panel. The windows-based computer program CALDose X 5.0 was utilized in the current investigation to increase the speed and efficiency of the patient dosimetry process. CALDose X 5.0 is a software tool that calculates INAK based on an X-ray tube output curve and the entrance surface air kerma (ESAK) by multiplying the INAK with a backscatter factor, as well as organ and tissue absorbed doses and EDs for posture-specific female and male adult phantoms, using conversion coefficients normalized to the INAK and ESAK.

A comprehensive examination was conducted on 146 adult patients, encompassing chest and skull X-ray procedures. The examinations took place at several medical facilities, including the police hospital, health insurance center, customhouse hospital, and seaport hospital. In this study, the hospitals are labeled as I, II, III, and IV, respectively.

Table 1 presented the demographic information of all patients, including their age range (18-77) years, weight range (54-112) kg, and height range (149-188) cm. The parameters for the skull and thoracic regions were as follows: the kilovolt peaks (kVp) varied from 65 to 75 for the skull and from 70 to 90 for the thoracic region, while the tube current (measured in milliamperes, mAs) ranged from 9 to 15 for the skull and from 25 to 55 for the thoracic region.

In this prospective non-randomized study, we enrolled 146 patients (78 for the thoracic spine and 68 for the skull examination from the Red Sea State Hospital, Red Sea State, Sudan in June-December 2022. The average age was 42.47 ± 13.90 years with normal BP (120/80 mmHg) were recruited in the study as a healthy control group. The study protocol was approved by the local ethics committee, and informed written consent was obtained from the parents of the patients and volunteers before entering the study.

Exclusion criteria included the presence of autoimmune disease, acute kidney injury or with unsatisfactory vascular access or any other known condition that would alter cytokine levels. Moreover, none of the patients had received antibiotics, anti-inflammatory or corticosteroid medications during the study period.

Table 2. The mean and the median of ESAK (mGy) and INAK (mGy) for all adult examinations

Exam	ESAK		INAK	
	Mean	Median	Mean	Median
Skull	0.52 ± 0.45	0.58	0.47 ± 0.21	0.52
Thoracic	0.77 ± 0.11	0.82	0.58 ± 0.30	0.67

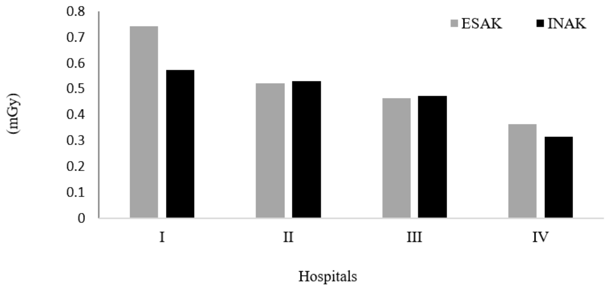

Figure 1. Comparison of mean of ESAK and INAK values for skull exam between different hospitals (Source: Authors' own elaboration)

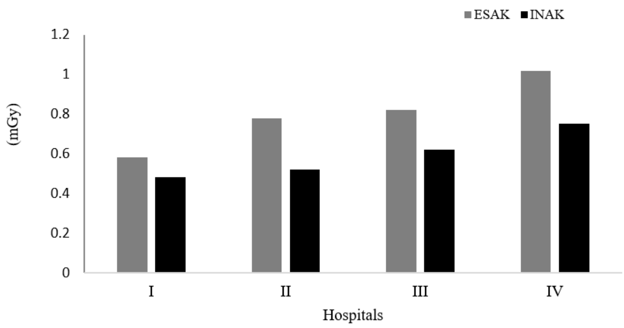

Figure 2. Comparison of mean of ESAK and INAK values for thoracic spine exam between different hospitals (Source: Authors' own elaboration)

RESULTS AND DISCUSSION

Table 2 displays the mean and median value of ESAK (mGy) and INAK (mGy) for all examinations. There was considerable disparity in the dosages administered to patients undergoing the same type of X-ray procedure across different facilities. Patient dose variability may be affected by factors such as patient weight, tube voltage, and tube current time product. The dosage levels of the thoracic spine examination exceeded those of the skull exams.

The study revealed significant disparities in patients' ESAK and INAK for skull and thoracic spine examinations across different hospitals. This could be attributed to a distinct assortment of exposure variables (**Figure 1** and **Figure 2**).

Table 3 shows the comparison of ESAK of present study with ESAK from previous studies, mean was taken as value for

Table 3. Comparison of ESAK for the present study with ESAK from previous studies

	ESAK (mGy) (skull)	ESAK (mGy) (thoracic)
Present study	0.52	0.77
[10]	0.85	2.58
[11]	1.01	N/A
[12]	1.08	1.90
[13]	1.20	N/A

comparison. The results were less than the previous studies for both skull and thoracic spine examinations.

The main purpose of the present study was to assess the patient entrance surface dose during X-ray exams of the skull and thoracic spine in the Red Sea State, Sudan. This evaluation was conducted at four hospitals, where a total of 144 X-ray images were captured from adult patients with diverse features (as shown in **Table 1**). **Table 1** demonstrates that the tube voltage employed for different X-ray exams varies based on the specific type of test. The investigation utilized tube voltages ranging from 65 to 75 kVp and mAs ranging from 9 to 15, which were similar to the findings in [14]. The tube voltage utilized for thoracic spine tests varied from 70 to 90 kVp, while the tube current ranged from 25 to 55, which is consistent with the findings of the study in [15]. The research revealed a wider spectrum of tube loads than anticipated, primarily attributed to variations in the patients' body mass index. Consequently, there was reduced variability in the alignment of the patients' bodies.

Table 2 presents the mean and median values of ESAK (mGy) and INAK (mGy) for all examinations. There was considerable disparity in the dosages administered to patients undergoing the same type of X-ray procedure across different facilities. The variability in patient dose may be affected by factors such as patient weight, tube voltage, and current-time tube product. The dosage levels of the thoracic spine examination exceeded those of the skull exams. Several factors contribute to the radiation dose received by the patient [16], including as the quality and condition of the imaging system, the features of the patient and the specific anatomical areas being examined, and the technical components of the procedure. The fundamental objective in radiography is to determine the optimal level that ensures the necessary quality of diagnostic images. This involves identifying the parameters that can achieve this level of quality while minimizing the amount of radiation exposure to the patient, in accordance with international dose reference values. The variation in patient dosages per treatment may be attributed to the inclusion of several projections (anteroposterior, lateral, and oblique views) in each procedure, as per the department protocol or the request of the referring physician.

CONCLUSIONS

Upon comparing the findings with the previous studies, it was evident that the value of the dosages is lower than those of the previous studies in both skull and thoracic spine examinations. The variability in dosages is attributed to the differences in X-ray equipment used. This variation can be attributed to the inherent characteristics of X-ray systems and the type of imaging processing used.

Author contributions: MAS: preparation and writing the initial draft of manuscript, editing, proofreading, arrange the data as a scientific article, response to reviewers, corrections in whole manuscript, and proof correction; **AA:** ideas, conceptualization, methodology, resources, validation, and visualization; **MAH:** editing, proofreading, and revision; **MA:** synthesizing study data and application of statistical mathematics; & **IGA:** coordinator and application of statistical mathematics. All authors have agreed with the results and conclusions.

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Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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