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Recent Advancements and Perspectives on Entrance Skin Dose and Cancer Risk for Patients Undergoing Diagnostic X-Ray Examination

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Abstract
Advancements in technology and medicine have increased radiation use, with radiology examinations being the primary man-made source of radiation exposure for the general public. Over 90% of the ionizing radiation exposure today comes from man-made sources. However, because ionizing radiation is linked to a cancer risk, its use in medical imaging for diagnosis should adhere to safety regulations and be optimized. This study aims at providing recent advancements and perspectives on entrance skin dose and cancer risk. Many studies have been published around the world on how to tackle the dangers behind the ionizing radiation that is exposed to patients. The Recent advancements and perspectives on entrance skin dose and cancer risk undergoing diagnostic x-ray examination were discussed in detail, including how the dose was reduced for patients and even the best method to adopt, as well as the concept of absorbed dose in the human body from exposure to radiation, particularly in the context of diagnostic X-ray examinations. It emphasizes the importance of measuring the energy deposited per unit mass, expressed in joules per kilogram (Jkg^{-1}) or in the unit gray (Gy). The review also touches on equivalent dose, which takes into account the type and energy of the radiation, and effective dose, which is designed for radiogenic risk assessment. The study reviewed various methods for calculating

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entrance skin dose (ESD) in X-ray examinations, including both direct and indirect methods, and presents results from different research studies that have used these methods to measure ESD in patients undergoing diagnostic X-ray examinations. The paper provides a comprehensive overview of the importance of monitoring and optimizing radiation doses in medical imaging to ensure patient safety.

Keywords: Entrance Skin Dose (ESD); Cancer Risk Probability (CRP); Thermo Luminescence Dosimeter (TLD); Diagnostic Reference Levels (DRLs); Effective Dose (ED); Focus to Skin Distance (FSD); CALDOSE_X software. Lateral (Lat)

INTRODUCTION

The diagnosis and treatment of many medical diseases in both adults and children have improved as a result of the use of medical imaging in medical operations. Medical imaging methods come in a variety of modalities, each utilizing a unique set of technology and techniques. Ionizing radiation is used in medical examination which produces images of the body through fluoroscopy, radiography (traditional X-ray), and computed tomography (CT). Ionizing radiation is a type of radiation with enough energy to possibly damage DNA and increase a person's lifetime chance of getting cancer (Ilori *et al.,* 2018). During diagnostic X-ray exams, ionizing radiation is utilized to provide images of the inside of the body. X-rays are useful for identifying illnesses and injuries, but they also expose people to ionizing radiation, which can have negative effects on their health (Bekas *et al.*, 2017). Diagnostic examinations are essential for patient management worldwide, with about 80% of patients undergoing x-ray examination (Hamid, 2020). In 2016, 257 million examinations were carried out, with the patients' collective doses amounting 71,000mSv (Bushra *et al.*, 2022). The frequency of radio diagnostic procedures is increasing due to the development of novel radiological tests with high radiation doses (Saeed *et al.*, 2022). Advancements in technology and medicine have increased radiation use, with radiology examinations being the primary man-made source of radiation exposure for the general public. Over 90% of the ionizing radiation exposure today comes from man-made sources (Hamaoka 2022). The energy of radiation types falling under the category of "ionizing radiation" which is sufficient to remove electrons from atoms. The spectrum of ionizing radiation includes gamma rays and x-rays, as well as frequencies of about 900 THz and above (Srinivasan *et al.,* 2014). However, because ionizing radiation is linked to a cancer risk, its use in medical imaging should adhere to safety regulations and be optimized (Tsapaki 2020). Diverse radiation types or energies at equal doses have diverse physiological effects on various tissues. Induced cancer rates range from 1.2 to 2% of population in developed countries (Bushra *et al.,* 2022).

Dose monitoring is essential to improve radiation protection for patients and provide the least amount of radiation during exams in radiology (Rabiu et al., 2022; Taha *et al.,* 2023). Entrance surface dose (ESD) is an important variable in determining the amount of radiation a patient receives during a single radiography exposure (Ofori *et al*., 2014). The dose of organs and tissues of patients undergoing X-rays in radiographic examinations is primarily dependent on entrance surface dose (ESD). To ascertain the risk in a radiographic examination, it is necessary to know the absorbed dose by each organ and the risk associated with it (Panahi *et al.,* 2021). Although these methods are typically impracticable, some types of dosimeters, such as thermoluminescent dosimeters (TLDs), optically stimulated luminescence dosimeters (OSLs), or radiochromic films, can be used to directly assess the patient's radiation exposure. However, indirect patient dose monitoring remains a useful tool for estimating radiation exposure. Utilizing a dosimetric software technique from direct measurements of X-ray output (Andrés *et al.*, 2017). Periodic assessment of patient doses is important, as the benefits and diagnostic value of the appropriate radiological procedure outweigh the anticipated radiogenic risk. Inappropriate radiological procedures result in unnecessary increase in patient risk (Bushra *et al.*, 2022).

It is important to consider the possible risks of ionizing radiation and to optimize the use of X-ray examinations to guarantee patient safety and reduce radiation exposure (Smaglyuk *et al.*, 2023). The primary goal of this study is to evaluate the modalities of investigating the ESD and cancer risk, but it will also give participating hospitals insightful input on their existing procedures. As a result, during the reviewed, information besides the dose measurement was also gathered. This covers the kinds of tools and methods used to take images, including exposure factors, focus to skin distance, grid usage, projections, and Automatic Exposure Control (AEC).

Radiation Dose

When ionizing radiation penetrates the human body or an object, it deposits energy. The energy absorbed from exposure to radiation is called a dose. Radiation dose quantities are described in three ways: absorbed, equivalent, and effective (Canadian Nuclear Safety Commission, 2023).

Absorbed Dose

The absorbed dose is the amount of radiation energy an organ or tissue absorbs per unit mass, used to determine the likelihood of harm. It is now represented by joule per kilogram (J/kg) and is called "Gray" (Gy). However, it is not suitable for comparing stochastic effects (Shah *et al.*, 2015).

The energy absorbed in the human body from exposure to radiation is called an absorbed dose. The absorbed dose is measured in a unit called the gray (Gy) (Canadian Nuclear Safety Commission, 2023b). According to Tootell *et al.* (2014). There is a chance that some of the radiation energy will be deposited when ionizing radiation interacts with materials. The quantity of energy deposited per unit mass refers to the absorbed dose and is expressed in joules per kilogram (Jkg^{-1}). The absorbed unit in SI is the gray (Gy). Also, according to Bell and Jones (2020), Issa *et al.* (2019), and ICRP (2007), the amount of energy deposited in a medium by ionizing radiation is measured by the term "absorbed dose." With the unit joules (J) per kilogram (kg) and the equivalent energy deposited per unit mass of a material, it is also known as gray (Gy), where 1 Gy = 1 Jkg^{-1}. It is not possible to predict the anticipated biological effect of the absorbed dose. For example, 1 Gy of photon radiation would not be as harmful to biology as 1 Gy of alpha radiation (Bell and Jones, 2020).

Equivalent Dose

In addition to the absorbed dose, the kind and energy of the radiation also affect the likelihood of tissue damage. According to the International Commission on Radiation Protection (ICRP, 2007), radiation weighting factors (W), multiplying the absorbed dose refers to the equivalent dose denoted by the symbol (H_T). Equivalent dose is calculated for individual organs. It is based on the absorbed dose to an organ, adjusted to account for the effectiveness of the type of radiation. Equivalent dose is expressed in millisieverts (mSv) to an organ (Rabiu *et al.*, 2022). To determine the equivalent dose, appropriate weighting factors that take into account the various relative biological effects can be used (Bell and Jones, 2020). Absorb dose can be determine using equation (1) (Nikzad *et al.,* 2018).

$$H_T = DXW_R \quad 1$$

where H_T is the equivalent dose in Sieverts (Sv), D is the absorbed dose in gray (Gy) and W_R is the radiation weighting factor

Effective Dose

The effective dose was created to enable radiogenic risk assessment in cases where radiation levels to different organs differ (Damilakis *et al.,* 2010). In the radiological protection system of the International Commission on Radiological Protection (ICRP, 2007), an effective dose is a dose quantity. It is the tissue-weighted total of the equivalent doses in all designated human body tissues and organs. It is a representation of the stochastic health risk to the entire body, which is the likelihood that low levels of ionizing radiation may cause cancer and have genetic repercussions (ICRP 2012). According to Nissren *et al.* (2023), Rabiu *et al.* (2022), Safoora *et al.* (2018), Jokar *et al.* (2023) and Nikzad *et al.* (2018), an effective dose is calculated for the whole body. It is the addition of equivalent doses to all organs, each adjusted to account for the sensitivity of the organ to radiation. The effective dose is expressed in millisieverts (mSv). Effective Dose (E, mSv) can be determined using the equation (2) (Rabiu *et al.,* 2022).

$$E(mSv) = \sum_T W_T \times H_T \quad 2$$

Where: (W_T) is the weighting factors for the organ or tissue (T) and (H_T) is the equivalent dose.

Entrance Skin Dose

The entrance skin dose (ESD), is the measure of the radiation dose that is absorbed by the skin as it reaches the patient. Entrance skin dose is a directly measurable quantity, often, measured using thermo luminescent dosimeters (TLD) (Muphy *et al.,* 2023). According to Bell and Murphy (2017), the amount of radiation absorbed by the skin at the point where the X-ray beam enters the body is known as the entrance skin dose, or ESD. For the purpose of quality control and optimization in radiography departments, it is frequently utilized as a benchmark measurement (Aliasgharzadeh *et al.*, 2015). However, because it ignores tissue sensitivity, penetration, and the region of the X-ray beam, it is a poor indicator of radiation danger. ESD, which is expressed in milligrams (mGy), is used in ordinary radiography to create diagnostic reference levels (DRLs). These DRLs provide a standard for the efficient use of medical radiation and guarantee that departments follow radiation protection guidelines (Abdallah, 2021).

Studied Projections

Although the entrance skin dose is predicted in all radiography investigations utilizing ionizing radiation, this does not appear to be achievable in practice right away because it takes a great deal of data and work to attain (Seeram and Brennan, 2017). The study involved the eight most often conducted diagnostic x-ray examinations, which are as follows: anterior posterior (AP) abdomen, AP pelvis, AP and Lat pelvis, AP and Lat lumber spine, and PA and Lat skull (Sami *et al.,* 2015). The most common views AP and LAT. In the PA view, the X-ray source is positioned so that the X-ray beam enters through the posterior (back) of the chest and exits through the anterior (front), where the beam is detected. To obtain this view, the patient faces a flat surface behind which the X-ray detector is located. A radiation source is placed behind the patient at a standard distance (usually 6 feet, 1.8 m) and the x-ray beam is directed at the patient (Harrison & Streffer, 2007).

Entrance Skin Dose Calculations

The quantity of radiation that the skin absorbs at the point where the x-ray beam enters the body is known as the entrance skin dose, or ESD. It is an essential variable in figuring out how much radiation the patient actually received during a radiological examination. When it is not possible to measure the maximum radiation skin dose (MSD) in real time during cardiac intervention operations, the ESD is utilized to estimate the MSD (Chida *et al*., 2009). The ESD can vary based on the type of examination, patient characteristics, and imaging parameters. For example, a study in Nigeria found that the ESDs measured for various x-ray procedures were below the maximum permissible limits set by the Nigeria Basic Ionizing Radiation Regulation, and there was a good correlation between the entrance skin doses and body mass index for the studied subjects (Rabiu *et al*., 2023).
For the calculations of ESD, different methods were reviewed. These methods include both direct and indirect methods.

Direct Method (Using TLDs)
The entrance skin dose (ESD) in X-ray examinations is frequently measured using the thermoluminescence dosimeter (TLD) method. TLDs come in different shapes, including powder, cubes, rods, square or circular chips. Since TLDs are easily quantifiable, they are frequently used to establish diagnostic reference levels (DRLs), which maximize medical radiation use while upholding radiation protection guidelines (Bell & Murphy, 2017). Different papers were reviewed using this method; almost all the reviewed papers were dictating the same in terms of how to collect data from patients using the direct method, according to Greffier *et al.* (2021), Panahi e*t al.* (2021), Nikzad *et al.* (2018), Akpaniwo *et al.* (2019), Tamam *et al*. (2023), Akintayo (2020), Esu *et al*. (2021), and Alomairy *et al.* (2023). Firstly, the TLDs must be annealed using a TLD reader, and the TLD readers are of different types. Some of the authors, like Esu *et al*. (2021), Tamam *et al*. (2023), and Nikzad *et al.* (2018), used the RadPro TLDcube 400 reader, and the TLD Furnace Type LAB-01/400 was used to anneal TLD chips by Akpaniwo *et al.* (2019). While the remaining authors used the OSLD reader to anneal their TLDs, Secondly, TLDs must be calibrated for each batch. This calibration must be carried out for each interventional system, and this calibration is often done using a cobalt 60 radiation source to determine diagnostic energy levels (Akpaniwo *et al.,* 2019).

Table 1: Direct Method Studies

S/N	Findings	Conclusions	Authors
1.	The study found chest examination doses were higher than recommended limits, with range factors at Niger State General Hospital and Two-Tees X-ray center.	The research shows that entrance skin doses were higher than recommended limits may be as a result of inappropriate procedure or as a result of lack of quality assurance and safety control of the machines.	Sharifat *et al.,* (2009)
2.	The study found that the average dose of radiation exposure (ESD) and the average dose of exposure (ED) for various organs were different, with the risk of cancer varying depending on the cumulative dose. Male patients had a higher risk of cancer in the bladder, colon, liver, thyroid, esophagus, lung, and stomach, while females had a lower risk in the breast, lung, bladder, ovary, colon, liver, thyroid, esophagus, and stomach.	The 2016 ICRP health risk for seven examinations was around two cases per 10,000 people, with male patients having higher risks of lung and colon cancers based on age and sex, and female patients having higher risks of breast and lung cancers.	Nikzad *et al.,* (2018)
3.	The entry surface dose (ESD) for the chest, AP lumbosacral, vis, abdomen, and lateral lumbosacral were 0.26 mGy, 0.46 mGy, 0.71 mGy, and 1.3 mGy, respectively. The ESD	The UDUTH patient protection optimization was on level with regional and global best standards.	Akpaniwo *et al.,* (2019)

	values were discovered to be lower than diagnostic reference levels in the UK and comparable investigations conducted in Nigeria.		
4.	The study revealed that radiologists and technologists have varying effective doses of radiation, with radiologists receiving a lower doses and technologists receiving a higher doses and the average values was found to be 0.48±0.19 mSv,for radiologists and about 0.6±0.36 mSv for the technologist.	This investigation assessed annual radiation doses in radiology, finding lower effective doses for medical staff and patients, but occasional deterministic danger thresholds, requiring alerting by dose area product meters.	Tamam *et al.*, (2023)
5.	The mean ESD for facilities A and B was 2.92/4.12 and 3.01/3.67 mGy, respectively. The E for facilities A and B was 0.73 and 0.82 mSv. A good relationship was found between the DT with ESD, exit dose (ED), and DAP for facility A, but no relationship was found with other parameters.	A study in Aba, Abia State determined the mean and 75th percentile ESD for abdomen radiography using TLDs. The study found that the mean ESD was below NCRP 172 and AAPM/RSNA reported doses, while the mean E was 1.8 and 1.7 times higher than ICRP 103 and 60 reports.	Esu *et al.*, (2021)
6.	The Entrance Surface Dose (ESD) for Tin and Tsai, CALDODE_X, and TLD were found to be below the recommended DRLs by national and international regulatory authorities.	The local diagnostic reference level for this study is only limited to the Federal Teaching Hospital (FTH) Katsina.	Maaruf *et al.*, (2023)
7.	Significant variation in X-ray exposure parameters was discovered by the investigation between hospitals. For the hand, knee, and chest exams, the mean ESD values were higher than the national and international standards. Concerning values of 1.18 ±0.21 mGy and 1.54 ±0.31 mGy were found in the knee examination ESD, respectively. Direct and indirect ESD were shown to have a high positive association, indicating a considerable difference in exposure characteristics.	According to the report, in order to reduce patient radiation exposure while preserving diagnostic picture quality, Saudi Arabia's radiography facilities urgently need to implement standardized procedures and quality control methods.	Alomairy *et al.*, (2023)
8.	The investigation discovered a strong correlation between mAs and kVp variations and ED and ESD levels. The ESD range was 0.1075-0.8844, 0.2059-2.2997, 0.0729-1.44, and 0.03478-1.15 mGy for the Chest PA, Chest LAT, and Skull LAT exams, respectively. In comparison to other research, the mean ESD was lower than suggested DRLs, while the ED was greater.	To increase dose accuracy, this work makes use of modeling and experimental techniques. The reported ED is larger than prior research, and the mean ESD is lower than DRLs from the NRPB, CEC, and IAEA.	Panahi *et al.*, (2021)
9.	The investigation discovered that the TLD, 0.15 mGy, 0.12 mGy, 0.21 mGy, 0.23 mGy, 0.19 mGy, 0.31 mGy, and PA lateral chest AP, PA, and lateral ESDs were all less than the DRLs advised by international and national regulatory bodies. The three methodologies and projections used in this study have lower LDRs when compared to other worldwide and local reference levels.	The study uses both direct and indirect techniques to determine the Entrance surface dose (ESD) of patients exposed to conventional chest x-rays at Federal Teaching Hospital Katsina. The findings demonstrate patient safety throughout testing.	Abdallah, (2021)
10	According to the findings, 27 out of the 30 patients who were admitted fell inside the advised international limit by 5%. Doses in patients with cervical and prostate cancer fell within the acceptable range. 5.88% and 5.05% were the two individuals with breast	The study evaluates the department's radiation practice, revealing that dose values are within acceptable limits, but three cases were due to oblique beam projection, indicating a need for improvement in the department's radiation practice.	Adebayo *et al.*, (2013)

	cancer. 6.01% was the highest figure that was seen in a head and neck therapy.		
11	The study compares the European Commission's pediatric patient reference levels with ESD values. The results show that the mean ESD for chest AP doses was 0.0643 mGy in three age groups, which falls short of the European standard limit of 0.100 mGy. Older age group ESD values are higher than European reference levels in skull and abdomen AP radiographs. In the thyroid and esophagus skin regions, ESD values reached 10 mGy during a barium swallow examination. The investigation suggests that certain personnel misuse X-ray fluoroscopy on pediatric patients.	The study discovered that although technical factors vary, resulting in significant doses intervals, chest tests have ESD levels below European RL. In order to decrease pediatric doses without sacrificing image quality, the results recommend simplifying attitudes and fine-tuning parameters for pediatric radiography. This emphasizes the necessity of quality assurance processes.	Ribeiro and Yoshimura (2008)

Indirect Method (Dosimetry Software)

The indirect method of estimating entrance skin dose (ESD) is a essential aspect in the field of radiology and radiation protection. This method involves calculating the dose received by the skin at the entrance point of the radiation beam without directly measuring it. Instead, it utilizes various parameters and formulas derived from dosimetric principles. CALDose X software from Saint George's Hospital, London, to evaluate patient data and technical exposure parameters (Saeed & Almalki, 2022). This method is straight-forward and requires minimal additional parameters, but it also requires measuring the output of the X-ray machine (Yacoob & Mohammed, 2017). The ESD can be evaluated using measured kVp, mAs, FSD, and X-ray tube output. The CALDose_X program calculates the risks of cancer incidence and mortality based on the user's chosen examination (Nissren *et al.*, 2023). CALDose_X has several important characteristics, such as:

a). Organ and Tissue Absorbed Doses: The software evaluates the effective dosage's absorbed dose to organs and tissues using conversion coefficients (CCs) (Kramer *et al.*, 2008).

b). Cancer Risk for the Patient: CALDose_X also determines the cancer risk for the patient when they undergo radiography examinations (Nissren *et al.*, 2023).

c) Real-time Monte Carlo Calculations: The program can be accessed online as CALDose_X online, a web-based utility that uses the internet to do real-time Monte Carlo calculations for patient dosimetry in X-ray diagnosis (Kramer *et al.*, 2008).

d). Broad User Base: More than 700 registered users from more than 40 countries have used CALDose_X online. These users include radiologists, physicists, and other experts employed by hospitals, businesses, and health-related organizations (Kramer *et al.*, 2008). The most recent version of the program, CALDose_X 5.0, is available for download from the official website. The program has shown to be a useful resource for determining INAK, ESAK, KAP, effective dose, cancer risks, and doses to organs and tissues in diagnostic radiology (Gyan *et al.*, 2020).

Table 2: Indirect Method Studies

S/N	Findings	Conclusions	Authors
1.	During X-ray operations at SMH and FMC, the study documented the characteristics of X-ray radiation exposure for 150 patients, both male and female. A mathematical method was used to convert these values to entry surface dose (ESD).	The study estimates ESD and DRLs for upper extremity diagnostic X-ray examinations in major Kebbi hospitals, recommending increased filtration, quality radiograph	Samaila, (2022)

	The findings imply that, in order to minimize health hazards associated with X-ray exposure during radiological treatments, it is imperative to estimate radiation dosage and dose level.	standards, and dark room quality control.	
2.	The DRLs in the CR system and DR system were 0.4, 1.6, 3.1, 0.4, 0.3, 0.7, 0.6, 0.9, and 1.3 mGy for the chest posteroanterior (PA), lumbar spine anteroposterior (AP), lumbar spine lateral (LAT), cervical spine AP, cervical spine LAT, skull PA, pelvis AP, and abdomen AP, respectively.	Ghana's two teaching hospitals have proposed institutional DRLs in nine radiographic projections for the first time, serving as baseline data for local DRLs and a valuable tool for optimizing patient doses.	Gyan, (2020)
3.	The study discovered that for different exams, the mean and standard deviation of ESD and ED were 1.12mGy, 3.47mGy, 1.85mGy, 1.70mGy, 0.49mGy, and 2.85mGy. Just the chest/thorax examination was found to be in conformity with globally accepted diagnostic reference values when these findings were compared to published works. This suggests that more research is necessary, as well as steps should be taken to prevent exposure.c	The study used caldose_x software to evaluate ESD and ED of x-ray examinations at Murtala Muhammad Specialist hospitals Kano, revealing that optimizing technical and clinical factors significantly reduces patient doses.	Ali *et al.*, (2022)
4.	The obtained results showed that, with an average of 0.425 ± (0.299) mGy, the ESAK for the hospitals that were taken into consideration—AFH, ASH, ASGH, AHH, AZH, AHGH, MECC, AMGH, and AMH—were 0.67, 0.069, 0.59, 0.05, 0.79, 0.76, 0.48, 0.21, and 0.18, respectively. Compared to other X-ray facilities in this investigation, the ESAK in AZH was typically greater.	The study highlights the importance of determining patient doses (ESAK) to reduce unnecessary radiation in diagnostic radiography, recommending each hospital to optimize safety and x-ray inspection techniques.	Hussien and Mustafa (2021)
5.	According to the study, the mean ESAK (mGy) values for the different treatments were, in order, 0.2, 0.76, 97, 1.88, 1.25, 2.25, and 0.30 mGy. In eight planar radiography operations, the average ESAK values were marginally lower than in prior investigations, and there were smaller patient doses throughout the spinal cord, abdomen, hip, and skull regions.	The study evaluates the effectiveness of four diagnostic radiology departments' equipment and patient dosages; it finds ESAK values that are comparable to those of other studies, but it also emphasizes the necessity of uniform procedures and equipment performance.	Nissren *et al.,* (2023)
6.	The study reveals significant differences which show that Abdomen AP, Chest PA, Pelvis AP, Cervical LAT, and Skull AP, 4.36mGy, 1.43mGy, 4.71mGy, 1.45mGy, and 4.14mGy respectively. When compare the findings with the international recommendations the ESD values for chest and cervical were significantly higher than DRLs.	The study reveals that most routine diagnostic radiography exams result in patient doses exceeding DRLs, suggesting the need for a quality control program in medical imaging techniques. The research suggests hiring a qualified group of medical physicists to ensure good image quality and low dose patient.	Yacoob and Mohammed, (2017)
7.	The study reveals variations in ESD (mGy) in x-ray examinations, indicating a lack of standardized procedures and an exponential association between ESD and BMI.	The research focuses on an indirect method for determining entrance skin doses.	Hamza *et al.*, (2018)
8.	The study found that adult X-ray examinations' mean entrance skin doses were within the diagnostic reference dose level values obtained by the American College of Radiology and the International Atomic Energy Authority. However, the ESD for chest (AP) was 0.88 mGy. The study concluded that adjusting tube voltage, kV, and tube current product time, mAs, decreased the radiation dose to the chest X-ray by 58%.	The patients receive less ESD than international organizations report.The authors developed a computer software that can predict ESD before X-ray imaging, reducing the doses needed for typical exams, considering the patient's thickness in the computation.	Taha *et al.,* (2023)

9.	The Entrance Skin Dose (ESD) for children without POP varies from 0.3150mGy to 0.4990mGy, while for children with POP it ranges from 0.4371mGy to 0.5843mGy. Adults without POP have ESDs from 0.3826mGy to 0.6716mGy, while adults with POP have ESDs from 0.4851mGy to 0.9774mGy. The highest ESD of 0.6747mGy is less than the NNRA standard of 1mGy per year.	According to the study, exposure can be repeated for both adults and children with POP as the Entrance Skin Dose (ESD) for patients receiving forearm X-rays at Federal Medical Center, Jalingo, is not higher than the 1mGy standard recommendation.	Amaitem *et al.*, (2018)
10.	The study found that the dose ranged from 0.005664 mGy to 0.053149 mGy, with chest thickness ranging from 18 cm to 32 cm, was within the permissible 0.4 mGy limit.	The research shows that adult patients receiving X-ray examinations within the 0.4 mGy radiation protection level were properly maintained, indicating the need for quality assurance and control in X-ray radiography and radiology.	Oladotun *et al.*, (2022)
11.	cccThe diagnostic reference level and entrance surface air kerma had mean values of 0.64mGy and 0.67mGy, respectively. The diagnostic reference level and entry surface air kerma are marginally higher than the global reference values. This suggests that anyone who had X-ray examinations performed in the centers may be at danger. It is advised that standard operating procedures be created for the various X-ray examination processes.	The study assesses ESAK for patients in Abuja, Nigeria, and finds that the average patient may be at radiation risk due to slightly higher DRL than international reference values.	Alechenu *et al* (2023)
12.	In this study, patients between the ages of 10 and 15 participated. The imaging approach for the abdomen had the largest ED (378.46 µSv), whereas the skull examination had the lowest ED (10.40 µSv). The cervical vertebra view had the lowest ESD (0.97 ±0.21) while the lumbar spine projection (3.62 ±1.38 mGy) had the highest ESD. There was no statistically significant difference in the rates of radiation-induced mortality and cancer.	ESDs can be decreased by lowering patient doses, improving picture quality, and optimizing imaging settings. This lowers the risk of radiation-induced death and cancer incidence while also encouraging more research.	Jokar *et al.*, (2023)
13.	The results of the chest PA testing revealed a DAP range above the recommended limit of 0.12 Gy.cm2 to 0.42 Gy.cm2, with an average value of 0.23 Gy.cm2. The lateral DAP in the chest varied between 0.18 and 1.48 Gy.cm^2, which is double the standard value. DRL values were greater (average = 2.73) in lumbar spine lateral radiography.	DRLs are helpful in comprehending radiography examination procedures, however further research is required at hospitals connected to Birjand University of Medical Sciences in order to optimize dosage and lower patient exposure.	Zarghani *et al.*, (2023)
14	The study found significant variation in ESAK, possibly due to different exposure parameters. The mean values for Anteroposterior (AP) and lateral skull projection were 0.22 mGy, 0.24 mGy, 0.21 Gy.cm2, and 0.29 Gy.cm2, respectively. These values were significantly lower than commonly reported European DRL values, dosage values, and national reference levels. The observed levels of ESAK and KAP met the permissible and recommended dose limits.	The study confirms previous research on skull examination dose estimation using LDRL for AP and LAT skull X-ray projections, finding lower patient doses than previous studies, determining allowable X-ray doses.	Saeed *et al.*, (2022)
15	The study found that the mean effective doses for various spine conditions were 0.02 mSv, 0.01 mSv, 0.09 mSv, 0.05 mSv, 0.03 mSv, 0.13 mSv, and 0.41 mSv, respectively. The mean ESD calculations were 0.27 mGy, 0.43 mGy, 1.31 mGy, 1.05 mGy,	The caldose_x program was used to evaluate the ESD and ED of seven x-ray exams in public hospitals. The results showed that patient doses significantly decrease with the	Ofori *et al.*, (2014)

	0.45 mGy, 2.10 mGy, and 3.25 mGy. The findings were in line with international recommendations, except for the entrance skin doses for thorax, which were marginally higher than published works but below the IDRL.	optimization of technical and clinical parameters.	

The results obtained using CALDose X software to measure the entrance skin dose (ESD) and cancer risk in various radiographic examinations when considering Table 2 above, the studies show variations in ESD and cancer risk across different patient groups and organizations. For instance, Samaila (2022), Gyan (2020), Hussien and Mustafa (2021), Yacoob and Mohammad (2017), Hamza *et al.* (2018), Amaitem *et al.* (2018), Alechenu *et al.* (2023), and Zarghani *et al.* (2023), Ofori *et al.* (2014) reported ESD values for various body parts that were lower than local and international diagnostic reference levels, while Ali *et al.* (2022), Nissren *et al.* (2023), Taha *et al.* (2023), and Oladotun *et al.* (2022) revealed that the doses exposed to the patients were higher than recommended limits. Furthermore, Jokar *et al.* (2023) discovered that abdominal imaging procedures had the highest ED, while skull examinations had the lowest ED. The limitations of the studies, primarily the use of indirect methods and specific equipment, suggest the need for further research to improve the accuracy of dose measurements and enhance patient safety during X-ray examinations. These studies demonstrate the effectiveness of CADose X software in measuring ESD in various radiographic examinations and the variability of dose values based on different factors.

CANCER RISK PROBABILITY

The probability of cancer risk from diagnostic X-ray examinations, especially in pediatric patients, is a topic of concern. Research has shown that ionizing radiation used in medical imaging has the probability to establish carcinogenesis, and the increasing risk of thyroid cancer from low levels of medical diagnostic X-rays has been highlighted (Hmlsb, 2017). Organ dose, which is the absorbed radiation energy from ionizing radiation to an organ, is a better quantity for estimating the patient-specific risk than the effective dose, which is meant to be used only for populations and does not consider patient age or gender (Teferi *et al.*, 2011). A study conducted in Ethiopia estimated that the probability of induction of cancer, especially leukemia, from common diagnostic X-ray examinations in pediatric patients is about two to three times as high as in adults (Teferi *et al.*, 2011). CALDose X software from Saint George's Hospital, London, to evaluate patient data and technical exposure parameters (Saeed & Almalki, 2022). This method is straight-forward and requires minimal additional parameters, but it also requires measuring the output of the X-ray machine (Yacoob & Mohammed, 2017). The ESD can be evaluated using measured kVp, mAs, FSD, and X-ray tube output. The CALDose_X program calculates the risks of cancer incidence and mortality based on the user's chosen examination (Nissren et al., 2023). Moreover, according to the ICRP (2007), 103 publications suggested equation (3) to determine the cancer risk probability.

$$Cancer\ Risk\ Probability = 0.05 * \text{Collective Effective Dose} \qquad 3$$

OPTIMIZATION PROCESS

The optimization process on entrance skin dose and cancer risk involves various techniques and strategies aimed at minimizing radiation exposure and its potential impact on cancer risk. The optimization process can be done through either one of the below strategies.

Establishment of a quality assurance program

The reasons behind unnecessarily high patient dosages are typically linked to either inadequate equipment maintenance or inappropriate radiological procedures (IAEA, 2012).

To ensure that the optimization process is successful, a quality assurance procedure must be designed first. The quality assurance program is described by the World Health Organization (WHO) as a systematic effort to guarantee that images obtained during an X-ray imaging procedure are of high quality to consistently provide adequate diagnostic information at the lowest feasible cost and with the least amount of radiation exposure to the patient (Tsapaki, 2020). In addition to other clinical factors, such as the use of a contrast agent, the optimization procedure necessitates striking a balance between patient dose and image quality (IAEA, 2012). Quality assurance can only be done by some organization such as American Association of Physicists in Medicine (AAPM), the Institute of Physics and Engineering in Medicine (IPEM) of United Kingdom (UK).

Define the optimization team

It is recommended to form an optimization team comprising radiation technologists (radiographers), medical physicists, and radiologists. Every one of these experts plays a distinct part in the optimization procedure. When determining if adequate task-specific image quality is maintained, the radiologist offers input, and the medical physicist directs the optimization process by utilizing a variety of techniques previously mentioned (Gingold, 2017). In addition to these strategies, some specific measures can be taken to reduce radiation exposure:

a). Customizing scanning: You can minimize radiation exposure by modifying the scanning according to the patient's weight and size or the body part being scanned (Kim, 2018).

b). Testing and equipment maintenance: Regular testing and making sure all systems are operating as intended can assist lower radiation exposure (*Protecting Yourself From Radiation | US EPA*, 2023).

c). Reducing the number of unwanted scans: Reducing the number of unnecessary x-ray examinations or other imaging procedures can assist in minimize the overall radiation exposure (Kim, 2018).

d). Reducing the area of the body that is scanned or exposed to x-rays: By concentrating on the smallest feasible area of the body, radiation exposure can be minimized (*How to Reduce Exposure to Radiation - ORISE*, 2023).

By following these strategies and measures, hospitals can take steps to minimize patient exposure to radiation in various situations, such as medical imaging or radiological emergencies.

CONCLUSION

The reviewed provides information on various studies related to radiation exposure in medical imaging, specifically using X-ray machines and thermo luminescent dosimeters (TLDs). The studies have been conducted in different countries, including Nigeria, Iran, and Saudi Arabia, and involve different patient populations and examination types. The findings of the studies indicate that chest examination doses can be higher than recommended limits, which may be due to inappropriate procedures, lack of quality assurance, or safety control of the machines. The average dose of radiation exposure (ESD) and the average dose of exposure (ED) for various organs can vary, with the risk of cancer depending on the cumulative dose. Male and female patients have different risks of cancer in various organs, with male patients having a higher risk in the bladder, colon, liver, thyroid, esophagus, lung, and stomach, while female patients have a lower risk in the breast, lung, bladder, ovary, colon, liver, thyroid, esophagus, and stomach. The studies also show that the entrance surface dose (ESD) values for different exams, such as chest, AP lumbosacral, abdomen, and lateral lumbosacral, can vary. The ESD values for these exams were found to be lower than diagnostic reference levels in the UK and comparable investigations conducted in Nigeria, indicating that optimization was on level with regional and global best standards. The studies also found that radiologists and technologists have varying effective doses of radiation, with radiologists receiving a lower doses and technologists receiving a higher doses. This investigation assessed annual radiation doses in radiology, finding lower effective doses for medical staff and patients, but occasional deterministic danger thresholds, requiring alerting by dose area product meters. Overall, the studies suggest that there is a need for quality assurance processes and standardized procedures to reduce patient radiation exposure while maintaining diagnostic image quality. Additionally, there is a need for ongoing monitoring of radiation doses for medical staff and patients to ensure safety and minimize risks. The limitations of the studies, primarily the use of either direct or indirect method or specific equipment, suggest the need for further research to improve the accuracy of dose measurements and enhance patient safety during X-ray examinations. The findings contribute to the existing literature by emphasizing the importance of monitoring and standardizing radiation doses to ensure patient safety during X-ray examinations.

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