Asian Journal of Pharmaceutical and Clinical Research

Vol 18, Issue 8, 2025

Online - 2455-3891
Print - 0974-2441

Research Article

EVALUATION OF RADIATION DOSES USING A DAP METER DURING VARIOUS MEDICAL IMAGING PROCEDURES IN A TERTIARY HEALTHCARE HOSPITAL

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Received: 21 April 2025, Revised and Accepted: 12 June 2015

ABSTRACT

Objectives: The objective of this study is to evaluate dose reference levels (DRLs) to provide quality images with minimal radiation dose to patients during the X-ray examination by employing the as low as reasonably achievable principle (as low as reasonably achievable).

Methods: The DRLs were measured with a dose area product (DAP) meter (KERMAX-Plus SDP, model 120–210), and data were compared with other studies. The local DRL values were calculated at 75 % of the mean DAP value.

Results: The measured minimum DRL value for hand-anterior to posterior examination was 0.04 Gy.cm^2 and for routine chest-posterior to anterior view, it was 0.59 Gy.cm^2 in this study. The maximum measured DRL value was 2.75 Gy.cm^2 for lumbar spine lateral radiography, but this was also much lower than other reported studies.

Conclusion: The DAP meter provides a reliable estimation of DRLs values and assists in the optimization of radiation dose, without compromising image quality during the X-ray examination practice in a radiology department.

Keywords: Radiation dose, Medical imaging, Dose reference levels, Dose area product meter, Local dose reference level, As low as reasonably achievable.

 DOI: http://dx.doi.org/10.22159/ajpcr.2025v18i8.54974. Journal homepage: https://innovareacademics.in/journals/index.php/ajpcr

INTRODUCTION

Today, X-rays are used as a primary scientific tool to diagnose and treatment of diseases in hospitals [1,2]. In the present scenario, the use of X-ray imaging and facilities are increasing day by day, but assessment of radiation dose is required during the medical imaging procedure in the radiodiagnosis department. In fact, in diagnostic radiology, doses are very low, but it is the largest source of man-made radiation and contributes the maximum radiation to the environment [3,4]. Therefore, knowledge of radiation output measurement plays a key role in obtaining the best quality images and reducing radiation hazards. This radiation dose assessment helps to know about real radiation risks and imaging techniques. There are three main key pillars for radiation protection purposes: justification, optimization, and dose limits. Each medical imaging procedure must be justified by its harm and benefits. After justification, dose optimization needs to be done by employing the as low as reasonably achievable principle [5-9]. Dosimetry is another method to optimize radiation dose to patients. Therefore, dosimetry is considered in the quality assurance (QA) program, and as a result, dose reference levels (DRLs) are achieved easily. This DRL is characterized by two components: Dose area product (DAP) and entrance surface dose (ESD). Initially, routine dosimetry and X-ray instrument quality control (QC) programs done in the United States have proven the use of DRLs and their effectiveness in decreasing patient doses during imaging. The results of ESD declined up to 50–70% between the years 1964 and 2004. In different cities or countries, DRLs can be defined as local dose reference levels (LDLs), while nationwide assessment is called national LDLs (NLDLs), but for similar medical imaging procedures, LDLs or NLDLS may be different values [10-16]. Various techniques exist for assessing the ESD, such as employing a DAP meter to quantify the overall radiation exposure considering the irradiated tissue area, utilizing a thermoluminescence dosimeter for direct measurement of the administered dose, or a few mathematical empirical formulas. DAP meter is a very simple and useful radiation dose descriptor that provides quick measured radiation doses of patients [17-20]. These measured radiation doses are directly proportional to the biological effects of radiation, depending on the dose and the part of the body being exposed to radiation [21,22]. Therefore, the DAP meter is helpful for the X-ray machine's functional evaluation and QA as well. The DAP meter value is independent of the distance (r) to the X-ray source but depends on applied KVp, mAs, or altering the field size, and provides its measurements in Gy*m^2. DAP meter readings vary for the same exposure factors or the same medical imaging procedure in conventional, computed radiography (CR), or digital radiography types of machines. The major advantage of the DAP meter is that, nowadays, it is built into X-ray machines. So that DAP meter values can be double-verified by applying another DAP meter below the collimator and creating LDRLs for an institute [23-25].

METHODS

This study was approved by the Office of the Ethics Committee, SMS Medical College and Attached Hospitals, Jaipur (Reference No: 731/MC/EC/2023) and conducted in the SMS Hospital, Jaipur, during the period from July 2023 to February 2024. X-ray machine's (CR system) QA and QC were performed as per Atomic Energy Regulatory Board guidelines before this study [26]. Radiation doses were measured for all adult patients (Age ≥15 years) who were prescribed medical imaging by the physician throughout this period. The exclusion criteria of this study were only a special view of medical imaging of the body part, which was requested sparingly and only when required. A total of 600 patients were selected randomly out of them, 356 were male and 244 were female. The physical parameters such as patient data (age, sex, height, and weight), applied exposure factors (kVp, mAs, and distance), and type of imaging projection of body part (lumbar spine – anterior to posterior [AP] or Lat, skull-AP or Lat, kidney ureter bladder -AP, chest-posterior to anterior [PA], flat plate abdomen, leg-AP, knee joint-AP, foot with ankle-AP, and hand-AP) were included for dose estimation and data accumulation.

DAP meter can measure the output of an X-ray tube having an energy range of 40–150 kVp; therefore, a calibrated DAP meter (KERMAX-Plus SDP, model 120–210) was used for this study. It was capable of working on temperatures −20°–+50°, relative humidity 10–90% (without condensation), and pressure 500–1062 hPa. This DAP meter comprises an ionization chamber and a DAP reader. First, the ionization chamber was attached under the collimator and connected to its reader with a connecting cable to provide readings within 1–3 S. Measured doses were obtained in Gy*m^2 units, which were converted into Gy*cm^2 for data analysis and comparison [27-29]. The mean, minimum, maximum, median, first, and third quartile values were calculated from DAP meter readings. The DAP meter data of this study were also compared with other studies for LDLs.

RESULTS

In this study, data from 600 patients were collected and summarized. Table 1 illustrates radiographic and demographic parameters, including patient age, weight, height, applied kVp, and mAs with average ranges. Table 2 summarizes the measured average DAP meter values of 12 types of radiographic projections. These DAP meter values were computerized to obtain mean, standard deviation (SD), minimum, maximum, median, first, and third quartile values. The minimum DAP meter values were found in the hand-AP projection. For the hand-AP projection, the minimum of average, maximum, and quartile 3rd values were 0.01, 0.05, and 0.04 Gy*cm^2. The DAP meter values were found to be maximum for the lumber spine-lateral projection. The minimum of average, maximum, and quartile 3rd values for the lumber spine-lateral projection were 1.49, 2.75, and 2.75 Gy*cm^2. The chest-PA projection is the most important and prescribed X-ray for the patient. In this study, the measured DAP meter values for chest-PA projection were found within range. The minimum of average, maximum, or quartile 3rd values were 0.28, 0.60, and 0.59 Gy*cm^2 for chest-PA projection.

Table 3 summarizes the ten types of X-ray imaging projections with the results of this study and another group, as Zarghani *et al*. (2023), Zarghani *et al*. (2015), Shandiz *et al*. (2014), Bouzarjomehri *et al*. (Iran-2004), and National Radiation Protection Board (1996) studies. This comparative data illustrates lower LDRLs values than other studies. Fig. 1 illustrates the mean and SD values in various radiographic projections in this study, and Fig. 2 illustrates the lower LDRLs when compared to Iran's (2004) LDRLs values.

DISCUSSION

Ionizing radiation is more harmful than non-ionizing radiation, it produces two types of effects known as stochastic and non-stochastic that depends on the type of radiation, energy, and exposure time. Stochastic effects appear after a threshold radiation dose, but non-stochastic effects have no threshold dose. Therefore, it is said that no radiation dose is safe. In the radiology department, low radiation doses are used for imaging purposes, which may affect chronic diseases, such as leukemia and cardiovascular diseases [30]. Simultaneously, numerous approaches are being actively pursued by researchers to identify the etiology and treatment of cancer; therefore, from the radiation protection point of view, radiation doses in each medical imaging procedure must be measured [31,32]. This study depicts the information regarding radiation doses delivered to the patients during medical imaging for different imaging projections. This patient data are used to create institutional LDRLs, and it was compared with other established DRL values to refuse errors and discrepancies. For individual patients, the maximum to minimum ratio of the DAP meter is varied by 0.2 in chest radiography, and this type of variation was also reported by

Table 1: The radiological and patient parameters (age, weight, height, applied kVp, and mAs). The radiological parameters help to calculate the dose, and patient parameters help to calculate the BMI and body separation

S. No.	Projection	Number*	Age (year)	Patient weight (Kg)	Height (cm)	Total voltage (kVp)	mAs
1.	Chest PA	50	36.5 (16–62)	56.82 (36–75)	165.9 (144–199)	59.980 (57–64)	10.660 (8–13)
2.	FPA	50	36.16 (18–60)	57.02 (40–75)	163.45 (130–190)	65.200 (60–70)	25.920 (20–32)
3.	KUB	50	36.59 (18–60)	56.78 (40–75)	165 (146–189)	70.00 (65–75)	41.633 (65–75)
4.	L.S.-AP	50	36.14 (18–60)	56.22 (37–70)	166 (145-188)	70.00 65-75)	41.633 (35–50)
5.	L.S. Lat	50	36.42 (18–60)	56.22 (37–70)	166.35 (145–189)	75.00 (70–80)	56.320 (40–65)
6.	Skull-AP	50	35.90 (17–60)	57.41 (40–75)	162.9 (140–194)	58.653 (56–62)	16.327 (13–20)
7.	Skull-Lat	50	36.898 (17–60)	57.408 (40–75)	162.9 (140–194)	58.655 (56–62)	16.377 (13–20)
8.	Pelvis-AP	50	36.020 (18–16)	56.204 (39–70)	166.25 (143–195)	70 (65–75)	40.653 (32–50)
9.	Leg-AP	50	36.143 (15–70)	55.061 (28–72)	170.6 (149–203)	52 (50–54)	8 (6–10)
10.	Knee Joint-AP	50	39.102 (16–63)	57.163 (28–70)	162.7 (140–187)	53.020 (52–54)	9.020 (8–10)
11.	Ankle c̄ Foot-AP	50	36.306 (16–60)	55.592 (28–70)	168.95 (142–194)	52.980 (52–54)	8.980 (8–10)
12.	Hand-AP	50	33.82 (15–70)	51.52 (28–77)	165.76 (146–189)	52.120 (50–54)	5.080 (4–6)

PA: Posterior to anterior, FPA: Flat plate abdomen, KUB: Kidney ureter bladder, AP: Anterior to posterior

Table 2: The mean±SD, minimum, maximum, first quartile, and third quartile of DAP meter values for X-ray examination

S. No.	Projection	Mean±SD	Min	Max	1st Quartile	Median	3rd Quartile
1.	Chest PA*	0.44±0.13	0.2837	0.6012	0.2867	0.4085	0.5910
2.	FPA*	0.36±0.10	0.234	0.5428	0.2765	0.3455	0.4619
3.	KUB*	2.46±0.73	1.2323	3.4081	1.6463	2.4169	3.4081
4.	L.S.-AP*	1.10±0.30	0.7246	1.5363	0.7246	1.0652	1.5363
5.	L.S. Lat*	2.16±0.51	1.4935	2.7516	1.4935	2.2585	2.7516
6.	Skull-AP*	0.29±0.10	0.1748	0.4215	0.1748	0.3365	0.4215
7.	Skull-Lat*	0.39±0.12	0.2559	0.5664	0.2559	0.3565	0.5664
8.	Pelvis-AP*	1.56±0.15	1.2565	1.8715	1.4516	1.5611	1.5896
9.	Leg-AP*	0.11±0.03	0.0621	0.1567	0.0621	0.1176	0.1567
10.	KneeJoint-AP*	0.13±0.02	0.1176	0.1567	0.1176	0.1375	0.1567
11.	Ankle c̄ Foot-AP*	0.13±0.01	0.1176	0.157	0.1176	0.1176	0.1567
12.	Hand-AP*	0.03±0.01	0.0192	0.0556	0.02525	0.0286	0.0456

*Values represent mean±standard deviation (n=50). PA: Posterior to anterior, FPA: Flat plate abdomen, KUB: Kidney ureter bladder, AP: Anterior to posterior

Table 3: Results of this study, DRLs with other study DRLs

Projection	This Study	Zarghani[a] (2023) conventional	Zarghani[a] (2023) Digital	Zarghani[b] (2015)	Shandiz[c] (2014)	Iran[d] (2004)	NRPB[e] (1996)
Chest PA	0.59	-	-	0.64	0.25	0.97	1
FPA	0.46	0.46	0.46	2.15	1.29	4.06	6
KUB	3.40	-	-	-	-	-	-
L.S.-AP	1.53	0.93	2.12	1.99	0.7	3.43	6
L.S. Lat	2.75	2.73	3.04	3.83	1.52	8.41	14
Skull-AP	0.42	0.30	0.38	1.22	0.42	2.85	3
Skull-Lat	0.56	0.21	0.31	1.01	0.39	1.93	1.5
Pelvis-AP	1.58	0.78	1.25	1.47	1.09	3.15	4
Ankle c̄ Foot-AP	0.15	-	-	-	-	-	-
Hand-AP	0.04	-	-	-	-	-	-

This table illustrates that various studies were performed from time to time, but the DRLs of this study are also closer to them. [a]Zarghani *et al*., 2023. [b]Zarghani and Bahreynl Tossi, 2015. [c]Shandiz *et al*., 2014. [d]Bouzarjomehri *et al*., 2004. [e]National Radiological Protection Board, 1996. PA: Posterior to anterior, FPA: Flat plate abdomen, KUB: Kidney ureter bladder, AP: Anterior to posterior

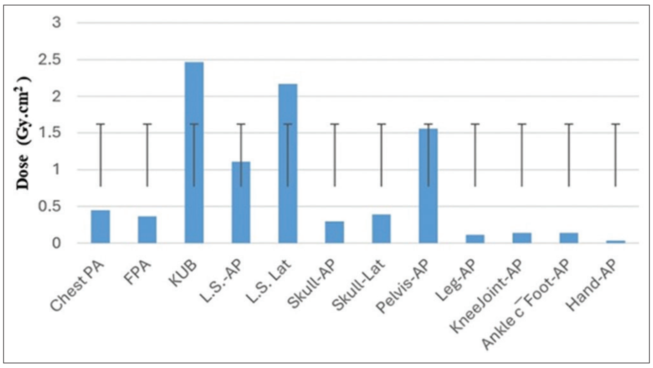

Fig 1: The bar graph illustrates the mean and standard deviation values in various radiographic projections. *Values represent mean±standard deviation (n=50)

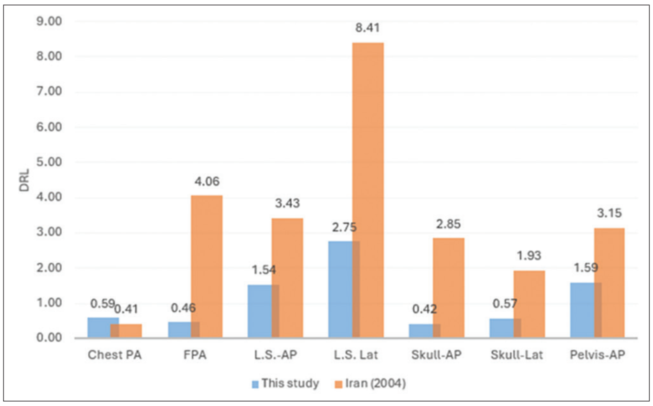

Fig 2: A comparison of the dose reference levels (DRL) values of this study with the Iran (2004) study, and the bar graph illustrates that the DRL values of this study are lower than Iran study

other studies [33,34]. In this study, the measured DAP meter values for all 12 types of radiological examination are closer to other studies, and the minimum DRL value is 0.04 Gy.cm^2 for hand-AP examination, and routine chest-PA view examination, it is found to be 0.59 Gy.cm^2 which is much less to other similar studies [35-38]. The maximum measured DRL value was 2.75 Gy.cm^2 for lumbar spine lateral radiography, but this was also much lower than other reported studies. In the present study, no significant relation was found between patient weight, height, age, or sex with DAP meter values, but a weighty correlation was noticed with applied kVp, mAs, collimation, and film-to-source distance to calculate doses by a mathematical formula. The results of this study are uniform with the literature [14]. This type of study helps to optimize patient's radiation doses without compromising image quality. LDRL values can be reduced by periodic QA and QC tests of machines as required, training of radiation technologists by conducting refresher courses, following DRLs and guidelines, using appropriate immobilization devices, and managing the duty hours of radiation technologists [39,40]. This type of study must be performed within a 3–5-year gap.

CONCLUSION

This study helps to create LDRLs for an institute, which provides a way to reduce patient radiation doses with better image quality. Radiation technologists can balance both risks and advantages in various medical procedures with the help of LDRL values. Periodic QA and QC increase the life of the X-ray machine.

ACKNOWLEDGMENT

This work is supported by the former Radiodiagnosis HOD of JK Lone Hospital, the former HOD of the Radiotherapy department, and my colleagues.

AUTHORS' CONTRIBUTIONS

Mr. Ajay Prajapati: Conceptualization, methodology, writing – original draft, and resources. Dr. Vijay Kumar Srivastava: Formal analysis and Software. Dr. Arun Chougule: Conceptualization, methodology, and data curation. Dr. Pooja Sharma: Editing and Software. Dr. Desh Deepak Singh: Supervision, project administration, writing – review and editing.

CONFLICTS OF INTEREST

None.

FUNDING

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sector.

STATISTICAL ANALYSIS

These DAP meter values were presented as mean±SD, minimum, maximum, median, first, and third quartile values. Statistical analysis was performed using Microsoft Excel 19.

ETHICS APPROVAL

Ethics approval for this study was granted by the office of the Ethics Committee, SMS Medical College and Attached Hospitals, Jaipur (Reference No: 731/MC/EC/2023).

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