Advances in Medical Physics and Applied Sciences

Original Article
DOI: https://doi.org/10.63187/ampas.43
Adv Med Phy App Sci, 2026; 2(2): 78-90

Radiation Dose Optimization and Parameter Trends in Digital Radiography: A Two-Period Comparative Analysis

ATAÇ, Gökçe Kaan [1], SANHAL, Ebru Özan [2], ALİŞAR, Kaan [3], İNAL, Tolga [4], ALHAN, Aslıhan [5], GÜNDOĞDU, Sadi [6], AYDIN, Gürdoğan [7]

[1] Bülent Ecevit University Medical School Department of Radiology, Zonguldak, Türkiye
[2] Akdeniz University Medical School Department of Radiology, Antalya, Türkiye
[3] VM Medicalpark Gebze Hospital, Kocaeli, Türkiye
[4] Ankara University Electric and Electronic Engineering Faculty, Ankara, Türkiye
[5] Ufuk University Medical School, Department of Statistics, Ankara, Türkiye
[6] Ufuk University Medical School, Department of Radiology, Ankara, Türkiye
[7] Cappadocia University, Cappadocia Vocational School, Nevşehir, Türkiye

Correspondence:
Gökçe Kaan Ataç Bülent Ecevit University Medical School Department of Radiology, Zonguldak, Türkiye
gokcekaan_atac@yahoo.com

Received: *2 February 2026*
Revised: *24 March 2026*
Accepted: *16 April 2026*

ABSTRACT

Purpose: This study aims to evaluate the temporal evolution of effective radiographic parameter preferences and radiation dose awareness among radiology technicians in Turkey, focusing on the transition within digital radiography and the implementation of dose optimization (ALARA) principles for adult and pediatric patients.

Methodology: A cross-sectional comparative study was conducted across two distinct periods (Period 1: N: 280, Period 2: N: 127). Data were collected via a structured online survey assessing technical parameter selections (kVp, mAs, and SID) for supine abdominal (KUB) and chest radiographs. Responses were categorized as low (0), optimal (1), or high (2) based on international. Statistical significance was determined using the Pearson Chi-square test ($p < 0.05$).

Findings: Significant shifts were observed in the participants' educational backgrounds ($p=0.0223$) and professional experience ($p=0.0361$). A marked improvement was identified in mAs optimization for adult KUB radiographs, with optimal selection rising from (0 % to 29%, $p < 0.001$). Correct SID usage also increased significantly for adult chest (24% to 38%, ($p=0.0199$) and pediatric chest radiographs (13% to 28%, $p < 0.001$). Conversely, pediatric KUB dose optimization worsened; optimal dose selection decreased from 27% to 15%, while high-dose preferences rose to 52% ($p = 0.035$).

Conclusions: While the findings indicate a positive trend in technical parameters like mAs and SID, pediatric radiation dose management remains a critical concern. The results highlight a persistent "education-practice gap," emphasizing the urgent need for targeted pediatric radioprotection training and standardized clinical protocols to ensure effective dose optimization.

Keywords: *Digital Radiography, Radiation Protection, ALARA, Dose Optimization.*

INTRODUCTION

Medical imaging technologies and practice have experienced a great technological development since the discovery of X-rays in 1895 [1, 2]. The transition from traditional screen-film systems to Computed Radiography (CR) plates and subsequently to direct Digital Radiography (DR) detectors represents a turning point in radiographical practice [1, 3, 4]. Globally, this shift has provided numerous advantages, such as enhanced and more stable image quality due to a wider dynamic range of the radiographic image and reduced image processing times [5–12]. It also helped to decrease the time and power consumed by technologists between table of radiography and film processing device [9–12]. However, the ease of post-processing offered by digital systems allows for the correction of suboptimal technical parameters may cause some problems such as overexposure without visible image degradation [13-18]. This phenomenon has introduced a latent risk of unnecessary dose which may increase the dose of patients, scientifically recognized as "Dose Creep" [19–21]. Technological advancement has not always been accompanied by a synchronized pace of standardization in clinical application protocols or user awareness [22–25]. In Türkiye, the radiological infrastructure has digitized rapidly over the past two decades within both the public and private sectors. Through the needs of developing standards, public and governmental demand and support, the technological equipment of hospitals has reached international standards, making DR systems the clinical norm of daily practice [26, 27]. Consequently, even with high-tech equipment, the risk of patients being exposed to unnecessary higher radiation or decreased image quality secondary to under exposure due to user preferences remains a contemporary challenge. Repeated imaging due to these deficiencies may represent an important radiation protection concern as it can lead to unnecessary cumulative radiation exposure to patients. [28-30].

The biological effects of ionizing radiation form the foundation of the ALARA (As Low as Reasonably Achievable) principle in radiological applications. Optimization, the core of the radiation protection culture, involves not merely dose reduction but determining the lowest energy level that maintains diagnostic integrity by image quality. International bodies, such as the International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and the European Commission (EC), guide this optimization process by establishing Diagnostic Reference Levels (DRLs) for various examinations. Image quality was also described in standard texts from same sources. Regarding radiation optimization, pediatric patients are distinctly separated from adults. Children's tissues and organs are 2 to 10 times more sensitive to radiation than those of adults [1–4]. Furthermore, their longer life expectancy increases the cumulative probability of radiation-induced stochastic effects like cancers [16–18]. Global initiatives, such as the "Image Gently" campaign, emphasize that radiographic parameters for children must not follow a "scaled-down adult" logic but must be specifically optimized for the pediatric anatomy, focusing on a balance of low mAs and appropriate kVp levels [31–34]. The literature indicates that the selection of technical parameters (kVp, mAs, SID) by radiology technicians is directly correlated with entrance skin dose (ESD) and organ dose [22–25]. Despite increasing technological capabilities, the persistence of deviations from reference values in clinical routines underscores the continued importance of user education and periodic audits. This study aims to contribute to the literature by analysing the temporal changes in the application habits of radiology technicians in Türkiye during the digitalization process and by identifying critical gaps in pediatric dose optimization. Even if the developments in technology in hospitals and health care system happened, the reflections on the habits and trends of professionals in their practice in the country was not evaluated in detail. Clarification of the improvements in performances and needs for further education may help for the delivery of high-quality radiology service. Scarcity of dedicated articles about the educational level of radiology technologists and their behaviour for the effective parameter usage in transition from film screen to digital radiography was the very first motivation of this study [26, 27].

MATERIAL AND METHODS

This study was designed as a cross-sectional, comparative research project to evaluate the radiographic parameter preferences and radiation dose awareness of radiology technicians. The questionnaire was written in an online survey site (Surveey.com). The survey page lets participants accept to join the survey, gives the questions and possible choices in same order, allow to go and come back between pages even leave the survey and join back with a pass code sent to the e mail of the responding person. A sample of the survey page is presented in Figure 1. The list of questions and possible options is presented in Table 1. Data were collected across two distinct time frames with 5 years of gap (Period 1; 2016) and Period 2; 2020) using a consistent online survey methodology. The study included approximately 280 radiology technicians/technologists in the first period and 127 in the second period, all of whom participated on a voluntary basis. The participants responded the questionnaire by their computers or mobile phones. The personal information was not asked and or recorded. The study protocol was reviewed and approved by the Cappadocia University Scientific Research and Publication Ethics Committee (Application Date: 23 June, 2020, Protocol No: 2020.05). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Electronic informed consent was obtained from all individual participants included in the study prior to their participation. Most of the data from first period was evaluated and processed by the same authors and presented in 37th National Congress of Turkish Society of Radiology in 2016. After completing the second period of the study in 2020, whole data evaluated and discussed in more detail within this text [8]. The research is designed in three parts. Data were gathered through a structured online survey instrument accordingly asking participants' demographic information, professional experience, and clinical practice habits. The survey consisted of three sections including the participants related answers in each section: The second section interested in preferences of participant radiology technologists' for tube potential (kVp), tube current-time product (mAs), and source-to-image distance (SID/FFD) were evaluated for both "Adult" and "Pediatric" patient groups across two common examinations: "KUB" and "Chest Radiography". This section has six questions. At the third section of the survey, questions focused on knowledge of the participants about maximum accepted entrance skin doses (ESD) for each examination and patient group was assessed, along with the frequency and conditions of Automatic Exposure Control (AEC) usage. This part of the questionnaire has two questions. The technical parameter responses obtained through the survey were gathered and estimated entrance skin doses (ESD) and deviation from the international radiation protection standards and established reference ranges in the literature were compared. Since the questionnaire were created to ask predefined possible exposure parameters, skin entrance doses were calculated with the formula [10].

ESD (mGy)=Outputref μGy / mAs × mAs × (dref / dskin)2× BSF

Outputref: Air kerma per unit mAs measured at a specific kVp and at a reference distance (usually 100 cm) (μGy/mAs). mAs: Product of tube current and exposure time. dref: Focal spot–to–detector distance. dskin: Focal spot–to–skin distance. BSF (Backscatter Factor): Factor accounting for radiation backscattered from the patient (approximately 1.3).

We used assumptions for calculation of skin entrance dose values of each exposure selections. Every answer of participants to the adult and pediatric child radiographies were used for the calculations. Tube current and distance to the detector (Source to Detector - SID) were collected from the answers. Standard patient dimensions were assumed for dose calculations. For adult patients (170 cm, 70 kg), anterior–posterior body thickness was assumed as 23 cm for abdomen and 21 cm for thorax examinations. For a 7-year-old pediatric patient, corresponding values of 15 cm and 13 cm were used, in accordance with published pediatric phantom data. Appropriate patient thickness was subtracted from given d ref distance to calculate d skin distance with formula of [dskin= dref (SID) – body part thickness]. Then the square of the ratio was created. The survey was based on virtual x ray machine and exposures were not real but selections from a series of possible options as described in Figure 1.

Tube output measurements were not available for this virtual X-ray unit, a typical tube output of 50 μGy/mAs at 80 kVp and 100 cm, as recommended in the literature, was accepted. Only one tube output value was used for all exposure calculations. Even if the value changes depending on the kVp value, same tube output value were assumed for adult and pediatric examinations, since tube output is a device-specific parameter independent of patient size. Because tube output is determined by X-ray tube characteristics and filtration, not by patient size, differences in pediatric dose arise from exposure parameter selection and backscatter conditions.

A backscatter factor (BSF) of 1.3 was assumed in the entrance skin dose calculations to account for radiation scattered back from the patient. This value is commonly used in diagnostic radiography for adult examinations and represents a typical backscatter contribution for photon energies in the range of 60–100 kVp, with standard field sizes and total filtration. The selected BSF value is consistent with recommendations and reference data reported by the IAEA, ICRP, and European Commission guidelines [10, 11]. The recommended exposure parameters and ESD values are presented in Table 4.

The To facilitate standardized analysis, each exposure parameter (kVp, mAs and SID) responses for and calculated ESD values were converted into a three-point coding system: 0 (Low): Values below the established reference range. 1 (Normal/Correct): Values within the accepted reference range. 2 (High): Values exceeding the reference range, potentially leading to unnecessary dose increases. Statistical evaluation was performed using professional analysis software (IBM SPSS Statistics. Version 29, IBM Corp., 2023). Descriptive statistics, including frequencies (n) and percentages (%), were calculated for demographic characteristics and parameter preferences.

Means and standard deviations were utilized for the distribution of numerical data. A post-hoc power analysis was conducted to evaluate the strength of the comparison between the two periods. For a medium effect size (w=0.3) and a significance level of alpha=0.05, the combined sample size (N=407) provided a statistical power (1-beta) of >0.99. This indicates a very high probability of detecting significant shifts in radiographic parameter preferences and dose awareness over the five-year interval.

Figure 1: A sample of survey pages showing the kVp choices for KUB study of adult and 7 years old child in same question. Participants may choose just one option for both series. The small pictures and drawings on the top left aimed to show the purpose questions. It also explains the body sizes of the virtual patients to describe the situation.

RESULTS

An analysis of the demographic and professional data of the radiology technicians included in the study revealed statistically significant differences in the participant profile between the two periods (Table 2 and 3). The distribution of educational institutions ($p = 0.0223$) and the duration of professional experience ($p = 0.0361$) showed a distinct change between the two periods. Conversely, no statistically significant difference was found between the periods regarding whether technicians received training on appropriate dosing based on patient height and age, or the sources of such training ($p = 0.0596$). The statistical comparison reveals a nuanced shift in the workforce profile, though this has not yet translated into improved clinical knowledge: The only parameter showing a statistically significant difference is the type of graduating institution ($p = 0.0223$). Between the two periods, there is a clear trend toward higher education levels, with an increase in Vocational School (Associate Degree) graduates and a decline in Health Vocational High School graduates. This reflects the modernization of radiology education in Turkey. Significant improvements in favour of Period 2 were recorded in radiographic parameters, particularly in tube current-time product (mAs) and source-to-image distance (SID) selections. For adult KUB radiographs, the percentage of participants selecting the correct reference range (code 1) increased from 0% in Period 1 to 29% in Period 2, demonstrating a highly significant statistical difference ($p < 0.001$). A similar positive trend was observed in distance selections; the application of the correct distance rose from 24% to 38% for adult chest radiographs ($p = 0.0199$) and from 13% to 28% for pediatric chest radiographs ($p < 0.001$). Additionally, the proportion of technicians performing adult chest X-rays within the normal kVp range increased from 14% to 22%, representing a significant statistical rise ($p = 0.0166$). Accuracy of the knowledge success of participants for Chest and KUB images were 17.4 % and 21.8 % for first and 24.2 % and 30.5 % for second period of study. Increase in accuracy values were 6,8 % and 8.7 % respectively (Table 4). In certain parameters, a deviation from reference values and a shift toward higher values were identified in Period 2. In adult KUB kVp preferences, the proportion of those within the normal range (code 1) decreased from 46% to 38%, while the rate of high kVp (code 2) usage increased from 29% to 41% ($p = 0.067$). This indicates a trend toward selecting higher tube potentials. Analysis of Entrance Skin Doses (ESD) revealed a concerning increase in the pediatric patient group. For pediatric KUB examinations, the rate of technicians choosing the correct dose range (code 1) decreased from 27% to 15%, while the rate of those selecting high-dose ranges (code 2) increased from 44% to 52%, a change that was statistically significant ($p = 0.0354$). In adult chest radiography dose preferences, the vast majority of participants in both periods (92% and 94%, respectively) remained clustered in the high-dose category, with no statistically significant change observed between the periods ($p > 0.05$). The summary comments highlight the shifting trends in technician behaviour, specifically noting the transition toward more optimized mAs and SID settings in the second period, contrasted with persistent challenges in pediatric dose management. The increase in technicians who reported receiving dose-specific training in school ($p = 0.0537$) is very close to the significance threshold. This suggests that newer curricula are integrating radiation safety more effectively, even if the overall change is not yet statistically conclusive (Table 4). Despite the significant change in the educational background of the technicians, there is no significant difference in their knowledge levels regarding ESD for either chest or abdominal radiographs. This indicates that while the "diploma type" is changing, the "practical knowledge" regarding patient safety remains static. This reinforces the "Education-Practice Gap" discussed in the earlier sections of the study (Table 5). Reliance on technical developments and default protocols installed into the control panels without scrutinizing of the real parameters needed in the particular scenarios can be an explanation of this result [24]. The comparison values from international standards are presented in Table 6.

Table 1. The list of questions asked in the survey and possible options which were possible to choose by participants. For the practical purposes, imaging parameter prefenences' of participants questioned in the beginning of digital survey form.

Question Number / Heading	Response Options
1- Select the tube potential (kVp) you use for "Supine Abdominal Radiography" (KUB) in adults and children.	Adult: 60, 70, 80, 90, 100, 110, 120 Pediatric: 60, 70, 80, 90, 100, 110, 120, 130
2- Select the mAs value (tube current-time product) for "Supine Abdominal Radiography" (KUB) in adults and children.	Adult: 3, 5, 7, 10, 13, 16, 19, 22, 25 Pediatric: 3, 5, 7, 10, 13, 16, 19, 22, 25
3- Select the required tube-to-detector distance (cm) for "Supine Abdominal Radiography" (KUB) in adults and children.	Adult: 70, 80, 90, 100, 110, 120, 130, 140, 150 Pediatric: 70, 80, 90, 100, 110, 120, 130, 140, 150
4- Select the required tube potential (kVp) for "Chest Radiography" in adults and children.	Adult: 60, 70, 80, 90, 100, 110, 120, 130, 140 Pediatric: 60, 70, 80, 90, 100, 110, 120, 140
5- Select the mAs value (tube current-time product) for "Chest Radiography" in adults and children.	Adult: 1, 2, 4, 8, 10, 15, 20, 30 Pediatric: 1, 2, 4, 8, 10, 15, 20, 30
6- Select the appropriate tube-to-detector distance (cm) for "Chest Radiography" in adults and children.	Adult: 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 180, 200 Pediatric: 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 180, 200
7- In which healthcare institution do you work?	University Hospital State Hospital Training and Research Hospital Private Hospital KETEM-Health Center Dispensary Primary Health Care Center
8- From which school did you receive your Radiology Technician/Technologist education?	Vocational School of Health Services - Radiology Vocational School of Health Services - another department Vocational School of Health - Radiology Vocational School of Health - another department On-the-job training in a hospital
9- How long have you been serving as a Radiology Technician/Technologist?	Less than one year, One-five years, Five-ten years, Ten-fifteen years, more than fifteen years.

10- Have you received training on taking radiographs at the most appropriate dose according to patient height and age? If so, where?	Received in high school/vocational school Did not receive training Received via in-service training Received in Vocational School of Health Services Received at association meetings and congresses Internship; Research; Other.
11- Which radiography device do you use in your department?	Fully digital radiography (DR) device Conventional X-ray device and computed radiography (CR) system Conventional X-ray device and film-screen system Panoramic Other.
12- What is the maximum accepted entrance skin dose (ESD) in milligrays (mGy) for the following radiographs?	PA Chest Radiography: 0.05-0.1, 0.1-0.5, 0.5-1, 1-2, 2-5, 5-10, 10-30 KUB: 0.05-0.1, 0.1-0.5, 0.5-1, 1-2, 2-5, 5-10, 10-30
13- Do you use the automatic exposure control (AEC) function of the device during radiography?	I know the AEC feature and use it on our DR device; I haven't heard of it/I don't know it; I know the feature but don't use it because I don't find it useful; My device does not have this feature; My device is not configured for this.
14- Did you also answer this survey when we conducted it in 2015?	No Yes

kVp: peak tube potential, mAs: milliampere second, KETEM: Cancer Early Diagnosis, Screening and Education Center, KUB: Kidney, Ureter, Blader, ESD: Entrance Skin Dose, AEC: Automatic Exposure Control, DR: Digital Radiography, CR: Computed Tomography, mGy: milligrays

Table 2. Table presents the comparative analysis of demographic profiles, professional experience, and radiation dose education.

Category / Question	Value (Code)	P1 Count (n)	P1 Percentage (%)	P2 Count (n)	P2 Percentage (%)
Educational Institution (Q8)	1 Vocational School - Radiology	199	71.1	100	78.7
	2 Health Vocational HS - Radiology	57	20.4	15	11.8
	3 Vocational School - Other	8	2.9	9	7.1
	4 Health Vocational HS - Other	4	1.4	2	1.6
	5 Master-Apprentice	12	4.3	1	0.8
Total		280	100.0	127	100.0
Professional	1 (<1 Year)	35	12.5	24	18.9

Experience (Q9)					
	2 (1-5 Years)	77	27.5	33	26.0
	3 (5-10 Years)	58	20.7	19	15.0
	4 (10-15 Years)	44	15.7	12	9.4
	5 (>15 Years)	66	23.6	39	30.7
Total		280	100.0	127	100.0
Radiation Dose Training (Q10)	1 Received in school	179	63.9	97	76.4
	2 In-service training	34	12.1	7	5.5
	3 Did not receive	57	20.4	18	14.2
	4 Other	10	3.6	5	3.9
Total		280	100.0	127	100.0

P1: Period 1 (First study timeframe), P2: Period 2 (Second study timeframe), Q: Question, HS: High School

Table 3. This table displays the Pearson Chi-Square test results comparing participants from Period 1 (N=280) and Period 2 (N=127). It identifies whether there is a statistically significant difference ($p < 0.05$) in the distribution of demographic profiles and radiation dose awareness between the two distinct timeframes.

Parameter	Chi-Square ($\chi 2$)	p-value	Result
Graduating Educational Institution (Q8)	11,409	0.0223	Statistically Significant
Radiation Dose Training Status (Q10)	7,655	0.0537	Not Significant
Professional Experience Duration (Q9)	8,288	0.0361	Not Significant
Accuracy of Chest ESD Knowledge	2,041	0.3603	Not Significant
Accuracy of Abdominal (KUB) ESD Knowledge	1,456	0.4829	Not Significant

ESD: Entrance Skin Dose, SID: (d_ref): Source-to-Image distance, KUB: Kidney, Ureter, and Bladder, Q: question

Table 4. A detailed breakdown of the technical parameter selections (kVp, mAs, and Source-to-Image Distance - SID) and resultant ESD for adult and pediatric patients across two distinct periods. The data is categorized using a standardized coding system where "1" represents values within the optimal diagnostic reference range, "0" represents values below the reference range, and "2" represents values above the reference range (indicating potential overexposure).

Examination	Parameter	Patient Group	Period 1 (0 / 1 / 2)	Period 2 (0 / 1 / 2)	Summary Comment
Abdominal (KUB)	kVp	Adult	67 / 131 / 82	26 / 49 / 52	Tendency for higher values increased in the 2nd period.
		Pediatric	200 / 47 / 33	83 / 25 / 19	Mostly values below the normal range.
	mAs	Adult	280 / 0 / 0	90 / 37 / 0	Transition to the correct range began in the 2nd period.
		Pediatric	31 / 193 / 56	18 / 75 / 34	Mostly remains within the normal range.
	SID	Adult	180 / 92 / 8	68 / 46 / 13	Distances were generally kept lower

					than reference.
		Pediatric	213 / 48 / 19	81 / 31 / 15	Use of low distance is common.
	ESD	Adult	278 / 0 / 2	122 / 0 / 5	Mostly doses below the normal limit.
		Pediatric	80 / 77 / 123	41 / 20 / 66	Dose distribution is heterogeneous in both periods.
Chest	kVp	Adult	239 / 39 / 2	95 / 28 / 4	Generally low kVp is preferred.
		Pediatric	247 / 17 / 16	105 / 8 / 14	Rate of low kVp is significantly high.
	mAs	Adult	0 / 28 / 252	0 / 14 / 113	Almost entirely high mAs values.
		Pediatric	0 / 25 / 255	0 / 14 / 113	Almost entirely high mAs values.
	SID	Adult	209 / 68 / 3	78 / 48 / 1	The proportion of normal range increased in the 2nd period.
		Pediatric	241 / 38 / 1	89 / 36 / 2	Correct distance usage improved in the 2nd period.
	ESD	Adult	6 / 18 / 256	1 / 7 / 119	Dose values are significantly high.
		Pediatric	0 / 22 / 258	0 / 13 / 114	Dose values are significantly high.

kV: kilovolt, mAs: milliampere-seconds, ESD: Entrance Skin Dose, SID: (d_ref): Source-to-Image distance

Table 5. Radiation protection knowledge levels among radiology technicians between two study periods (Period 1: N=280, Period 2: N=127). The "ESD Knowledge" sections reflect the accuracy of participants' understanding regarding acceptable entrance skin dose levels, categorized as low (0), optimal (1), or high (2) according to international reference standards.

Category / Question	**Value (Code)**	**P1 Count (n)**	**P1 Percentage (%)**	**P2 Count (n)**	**P2 Percentage (%)**
Chest ESD Knowledge	0 (Low)	71	25.4	37	29.1
	1 (Normal)	85	30.4	30	23.6
	2 (High)	124	44.3	60	47.2
Total		280	100.0	127	100.0
Abdominal (KUB) ESD Knowledge	0 (Low)	224	80.0	95	74.8
	1 (Normal)	26	9.3	14	11.0
	2 (High)	30	10.7	18	14.2
Total		280	100.0	127	100.0
Analiz grubu (Çocuk/Erişkin)	**Accuracy**	**P1**		**P2**	**Change**
Chest		17.4 %		24.2 %	+ 6.8 %
KUB		21.8%		30.5 %	+ 8.7 %

P1: Period 1 (First study timeframe), P2: Period 2 (Second study timeframe), Q: Question, HS: High School, ESD: Entrance Skin Dose, KUB: Kidney, Ureter, and Bladder, n: number of participants

Table 6. Standard exposure parameters were given for comparison to the values all participants' responses. ESD is one of the accepted DRL parameter for radiography exposures [10, 11].

Age	Exam	kVp	mAs	SID (cm)	DRL (ESD - mGy)
Adult	PA Chest	110 - 125	0.8 - 3.2	150 - 180	0.15 - 0.2
	KUB AP	75 - 85	10 - 25	110 - 115	4.0
Child (7yrs)	PA Chest	85 - 90	~1.1	180	0.07 - 0.12
	KUB AP	70	4.0 - 10.0	110	0.5 - 0.8

KUB:, kidney, ureter, blader, PA: posteroanterior, AP: anteroposterior, kVp: peak kilovolt, mAs: milliampere second, SID: Source to detector distance, DRL: Diagnostic Reference Level, ESD: Entrance Skin Dose, mGy: milligrays.

DISCUSSION and CONCLUSION

This study analyses the temporal changes in the technical parameter preferences of radiology technicians and the impact of these changes on radiation dose optimization during a period when digital radiography systems have become fully integrated into clinical practice. The findings indicate a positive development trend in fundamental geometric parameters such as mAs and source-to-image distance (SID); however, they also prove that a critical awareness gap persists regarding kVp selection and, specifically, pediatric dose management . International guidelines propose solid numbers of parameter ranges to use for frequently performed exposures searched in this study [10, 11].

Although the participants' graduation profiles and years of experience changed significantly between the two periods ($p < 0.05$), the lack of a statistically significant difference in their status of receiving dose-specific training ($p = 0.0537$) raises questions about the effectiveness of existing educational models [26,27]. While technicians may theoretically know the ALARA principle, their reliance on the automatic protocols of devices or their preference for "safe" (high) doses as a defensive radiology reflex continues to feed this education-practice gap. This habit is described before as a reason for keeping the patient doses high [21, 25, 27]

The most striking finding of the study is the trend toward reference ranges in mAs values for KUB radiographs . While none of the participants (0%) fell within the correct mAs range in the first period, this rate increased to 29% in the second period ($p < 0.001$), suggesting the emergence of technical awareness against the risk of "overexposure" among radiology staff. Given the wide dynamic range of digital systems, which allows for diagnostic images even at low doses, this optimization is significant for clinical outcomes [22–25]. Choosing the appropriate level of tube current is rather a task for automatic exposure control systems than technologists. Education about the benefits of this fundamental technology would be beneficial. Results revealed that the technologists are still using low mAs and not rely on AEC like a previous study. Even if the improvements in adult KUB parameters, the final state is away from the contemporary expectations. Large mAs scale selection or underestimation of patients' sizes importance also created incorrect exposure parameters in previous studies [4, 15, 20].

Similarly, the statistically significant increase in SID between the two periods demonstrates that the "distance" rule—a cornerstone of radiation safety—is being more actively applied in the clinic practice. Specifically, the increase in correct distance usage from 13% to 28% ($p<0.05$) in pediatric chest radiographs is a critical improvement in terms of reducing geometric magnification and lowering the entrance skin dose to the patient. SID is one of the few parameters directly affecting the patient dose and should be applied appropriately [3, 6, 21, 25, 28].

Despite positive technical developments, the findings regarding dose management in the pediatric patient group are concerning. The decrease in the proportion of technicians choosing the acceptable dose range in pediatric KUB examinations from 27% to 15%, alongside an increase in high-dose preferences to 52% ($p = 0.0354$), indicates that "Image Gently" principles are not sufficiently reflected in routine practice. Dose creep is described previously at the early days of digital radiology as a potential misbehaviour for technologists keeping the dose higher than necessary for being on the safe side for lower noise levels [1, 7, 15].

The tissue sensitivity of children, which is many times greater than that of adults, makes this trend toward increased doses radiobiologically risky. The underlying cause may be that technicians view pediatric patients as "scaled-down adults" and fail to establish the correct kVp balance (high kVp - low mAs), merely reducing the mAs value instead. Furthermore, the clustering of dose preferences in the "high" category—exceeding 90% for chest radiographs in both periods—proves that the phenomenon of "Dose Creep" remains the greatest threat in digital radiography as described in previous studies [20, 25, 33].

Strengths of the study can be abstracted below; one of the primary strengths of this research is its longitudinal approach, comparing data across two distinct periods. This allows for an objective evaluation of how technical parameter preferences have evolved alongside technological advancements in digital radiography. By specifically analysing pediatric vs. adult parameters, the study highlights critical risks such as "dose creep" in sensitive populations, providing high-value insights for radiation safety protocols. The study goes beyond simple data collection by identifying the discrepancy between technicians' formal training and their actual clinical choices, offering a roadmap for targeted institutional training. It may also be a deficiency of the study since very first data is from nine years ago and with new governmental regulations it is not allowed noncertified professionals as radiology technologists. The large sample size in contrast to the first period of this study (N=280) provides a solid foundation for statistical comparisons and reinforces the reliability of the identified trends.

On the other side the limitations of the study are summarized below. As the study relies on survey-based data, there is a potential for social desirability bias, where participants might select parameters, they know to be correct (theoretically) rather than those they routinely use in high-pressure clinical settings. The difference in the number of participants between Period 1 (N=280) and Period 2 (N=127) may limit the statistical power for certain sub-group analyses, although significant trends were still observable. The study evaluates "selected technical parameters" as a proxy for dose. While these correlate strongly with patient exposure, the research does not measure actual real-time doses (e.g., DAP or ESD) from live clinical cases. The findings reflect the tendencies within specific healthcare environments and may not be fully representative of all international radiology practices due to variations in equipment and local protocols. The last and may be not the least one is the period between the data collection periods and publication of them. It is necessary to perform similar audits to understand the current protocols and habits of the radiology professionals. Today, Dose Management Systems (DMS) replaced the old fashion surveys and it is easier and more reliable to have the automatic data collection via dedicated electronic data collection systems in hospitals. Sharing and comparing the exposure parameters and DRL indicators will create a trustful radiological environment for patients [31–34].

The lower response rate observed in the second period (25.4% vs 56.0%) may be attributed to increased professional workload and survey fatigue among healthcare workers during the post-pandemic era. However, the sample size remained statistically sufficient to provide high-power comparative analysis [22–25].

This study reveals that in the era of digital radiography, awareness of technical parameter optimization has increased for physical parameters such as mAs and distance, yet a regression has occurred in specific and sensitive areas like pediatric dose management.

In light of the data obtained through statistical analysis, the following conclusions have been reached:

1. Radiology technicians have begun to exhibit a more cautious attitude in mAs selection for adult patient.

2. The tendency to exceed dose limits in the pediatric patient group increased in the second period, indicating that pediatric radioprotection remains a clinical weakness.

3. Changes in the educational status of participants were not sufficiently reflected in clinical application results, particularly regarding kVp and dose selection.

In conclusion, radiation optimization is a user-dependent process that cannot be left solely to technological devices. There is a need to conduct more dose audits in hospitals, and provide training for technologists, especially for pediatric imaging protocols for applying appropriate use of imaging parameters in digital radiography. Establishing uniformity in standard imaging protocols across institutions will be the most effective solution for better imaging service and protection of patients from unnecessary radiation [33,34].

Conflict of Interest

There are no conflicts of interest and no acknowledgements.

References

1. Freitas MB, Pimentel RB, Braga LF, Salido F, Neves RFCA, Medeiros RB. Patient dose optimization for computed radiography using physical and observer-based measurements as image quality metrics. Radiat Phys Chem. 2020;171:108741. doi: 10.1016/j.radphyschem.2020.108768

2. Tamam N, Salah H, Almogren KS, Mahgoub O, Saeed MK, Abdullah Y, Thanh TD, Omer H, Sulieman A, Bradley DA. Evaluation of patients' and occupational radiation risk dose during conventional and interventional radiology procedures. Radiat Phys Chem. 2023; 205:110729. doi:10.1016/j.radphyschem.2023.110818

3. Reis CS, Caso M, Dolenc L, Howick K, Lemmen R, Meira A, Shatku F, Aymon E, Ghotra SS. Optimisation of exposure parameters using a phantom for thoracic spine radiographs in antero-posterior and lateral views. Radiography. 2023;29(2):416-422. doi: 10.1016/j.radi.2023.06.009

4. Hamd ZY, Alrebdi HI, Osman EG, Awwad A, Alnawwaf L, Nashri N, Alfnekh R, Khandaker MU. Optimization of chest X-ray exposure factors using machine learning algorithm. J Radiat Res Appl Sci. 2023;16(3):100615. doi: 10.1016/j.jrras.2022.100518

5. Dudhe SS, Mishra G, Parihar P, Nimodia D, Kumari A. Radiation dose optimization in radiology: a comprehensive review of safeguarding patients and preserving image fidelity. Cureus. 2024;16(1): e51523. doi: 10.7759/cureus.60846.

6. Soulis PI, Papavasileiou P, Bakas A, Lavdas E, Stogiannos N. Advancing exposure index in radiology for optimized imaging, accuracy, and future innovations. Cureus. 2025;17(1): e74122. doi: 10.7759/cureus.80819

7. Rosa IV, Furlan LN, Lykawka R, Anés M, Bacelar A, Dias JH. Analysis of exposure indices from digital radiography exams. Braz J Radiat Sci. 2024;12(1): e2304. doi: 10.15392/2319-0612.2024.2435

8. Ataç GK, Sanhal EÖ, Alişar K, İnal T, Alhan A, Gündoğdu S. Türkiye'de radyografide hasta dozları neden yüksek: radyografi tekniklerinin değerlendirilmesi. 37. Ulusal Radyoloji Kongresi; 2016. SS-59; p. 64.

9. Matsumoto H, Takei Y, Matsuda E, Masuda T. Measurement of the lens dose for radiological technologists during mobile radiography. Jpn J Radiol Technol. 2023;79(5):455-461. doi: 10.6009/jjrt.2023-1295

10. European Commission. European guidelines on quality criteria for diagnostic radiographic images in paediatrics. EUR 16261 EN. Luxembourg: Office for Official Publications of the European Communities; 1996.

11. European Commission. European guidelines on quality criteria for diagnostic radiographic images. EUR 16260 EN. Luxembourg: Office for Official Publications of the European Communities; 1996.

12. Gomes ST, Schwarz SC, Claus VT. Experimental evaluation of optimization in Cr and Dr digital radiography systems: a study with anthropomorphic phantom. Curr J Appl Sci Technol. 2023;42(24):1-10. doi: 10.9734/cjast/2023/v42i284200

13. Hariyati I, Hani ADF, Craig LA, Lestariningsih I, Lubis LE, Soejoko DS. Optimization of digital radiography system using in-house phantom: preliminary

study. J Phys Conf Ser. 2019; 1211:012028. doi: 10.1088/1742-6596/1248/1/012021

14. Almotairi YA, Almutairi TO, Almutairi FA, Otaibi ESA, Almutairi WA, Ishaq GF, et al. Strategies for minimizing repeated exposures in diagnostic radiography. Int J Community Med Public Health. 2024;11(3):1122-1126. doi: 10.18203/2394-6040.ijcmph20242300

15. Ching W, Robinson J, McEntee M. Patient-based radiographic exposure factor selection: a systematic review. J Med Radiat Sci. 2014;61(4):254-264. doi: 10.1002/jmrs.66

16. Knight SP. A paediatric X-ray exposure chart. J Med Radiat Sci. 2014;61(3):192-201. doi: 10.1002/jmrs.56

17. Ekem-Ferguson E, Issahaku S, Pokoo-Aikins M, Boadu M. Patient dose optimisation of abdominopelvic protocols during X-ray imaging. J Med Radiat Sci. 2025;72(1):15-24. doi: 10.1002/jmrs.70024

18. Rizzi E, Emanuelli S, Amerio S, Fagan D, Mastrogiacomo F, Gianino P, Cesarani F. Optimization of exposure conditions for computed radiology exams in neonatal intensive care. Open J Radiol. 2014;4(2):169-178. doi: 10.4236/ojrad.2014.41009

19. Roch P, Célier D, Dessaud C, Etard C. Using diagnostic reference levels to evaluate the improvement of patient dose optimisation and the influence of recent technologies in radiography and computed tomography. Eur J Radiol. 2018;105:18-25. doi: 10.1016/j.ejrad.2017.11.002

20. Creeden A, Curtis M. Optimising default radiographic exposure factors using Deviation Index. Radiography. 2020;26(2):121-126. doi: 10.1016/j.radi.2020.02.009

21. Steffensen C, Trypis G, Mander GTW, Munn Z. Optimisation of radiographic acquisition parameters for direct digital radiography: a systematic review. Radiography. 2021;27(2):684-691. doi:10.1016/j.radi.2020.08.012

22. Otomo K, Inaba Y, Abe K, Onodera M, Suzuki T, Sota M, Haga Y, Suzuki M, Zuguchi M, Chida K. Spatial scattering radiation to the radiological technologist during medical mobile radiography. Bioengineering. 2023;10(5):543. doi: 10.3390/bioengineering10020259

23. Alves AFF, Alvarez M, Ribeiro SM, Duarte SB, Miranda JRA, Pina DR. Association between subjective evaluation and physical parameters for radiographic images optimization. Physica Medica. 2016;32(11):1458-1463. doi: 10.1016/j.ejmp.2015.10.095

24. Vukani N, Lindiwe G, Bronwinc VW. Radiographers' awareness, understanding, and implementation of diagnostic reference levels in medical imaging: a scoping review. J Med Imaging Radiat Sci. 2025;56(1):101740. doi: 10.1016/j.jmir.2025.10210111

25. Rajendra Y. Knowledge, attitude, and practices of final-year diagnostic radiography students on setting exposure factors [Thesis]. Durban: Durban University of Technology; 2024.

26. Berksoy AE, Ekiz S. Radiology in Turkiye's healthcare system. J Radiol Med. 2025;2(4):81-83. doi: 10.51271/JRM-0040

27. Inat T, Atac GK. Dose audit for patients undergoing two common radiography examinations with digital radiology systems. Diagn Interv Radiol 2014; 20:100–4. doi: 10.5152/dir.2013.12122

28. Abdi AJ, Jensen KR, Pietersen PI, Jensen J, Hovgaard RL, Holmboe AKA, Gregersen S. Standardisation and optimisation of chest and pelvis X-ray imaging protocols across multiple radiography systems. Diagnostics. 2025;15(3):312. doi: 10.3390/diagnostics15121450

29. Yoon Y, Park H, Kim J, Kim J, Roh Y, Tanaka N, Morishita J. Proper management of the clinical exposure index based on body thickness using dose optimization tools in

digital chest radiography. Int J Environ Res Public Health. 2021;18(11):5681.

doi: 10.3390/ijerph18105203

30. Ramirez L. Best methods to reduce unnecessary radiation exposure. Int J Radiol

Imaging Technol. 2025;11:105. doi: 10.23937/2572-3235.1510136

31. Irsal M, Syuhada FA, Ananda YP, Putra AGP, Syahputera MR, Wibowo S, Kahar R.

Analysis exposure index as an optimization effort on examination chest posterior

anterior. J Vocational Health Stud. 2020;4(1):33-38. doi:

10.20473/jvhs.v4.i2.2020.50-54

32. Maeda T, Hara M, Yamasaki H, Nakahara M, Tanabe Y. Optimizing radiation dose

and image quality in neonatal mobile radiography. Radiat Prot Dosimetry.

2025;201(1):22-30. doi: 10.1093/rpd/ncaf080

33. ICRP, 2023. Optimisation of radiological protection in digital radiology techniques

for medical imaging. ICRP Publication 154. Ann. ICRP 52(3).

34. Jiang B, Hu J, Chen X, Wu X, Deng K, Yang H, Situ W, Jiang S. A deep learning AI

model for determining the relationship between X-ray detectors and patient

positioning in chest radiography. PLoS One. 2025;20(1):e0315421. doi:

10.1371/journal.pone.0333209