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Estimating the radiation surface dose and measuring the dose area product to provide the diagnostic reference level in panoramic radiography

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► ***Original article***

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ABSTRACT

Background: Panoramic radiography is one of the common dental imaging procedures using ionizing radiation. It is necessary to control the level of exposure and use the optimized levels. So, the current work aimed to estimate the surface absorbed doses of critical organ regions, namely thyroid and parotid glands. Moreover, dose area product (DAP) values were measured and a local DRL was then established for panoramic radiography. ***Materials and Methods:*** The data from 201 patients including 141 adults and 60 children (5-10 years) were used for this cross-sectional study. Seven panoramic radiography systems were selected from 6 radiology clinics in Yazd province. For each patient, 12 thermoluminescence dosimeters (TLD GR-200) were used to obtain the surface absorbed dose in both the thyroid and parotid gland regions. The DRL values were calculated using DAP values in terms of the ICRP recommendation. ***Results:*** The mean and standard deviation (SD) of thyroid and parotid glands' surface absorbed doses were equal to 60.6±3.7 and 290±12.4 µGy in the adult group, respectively. In the children group, these values were 40.7±2 and 189.3±11.5 µGy, respectively. Moreover, the local DRL values were obtained as 99.7 and 73.4 mGy.cm^2 for the adults and children groups, respectively. ***Conclusion:*** The higher surface absorbed dose values in the adult group can be related to the use of higher radiation parameters. The local DRL proposed for the adult and pediatric groups in the current study was relatively lower than those established by other reports, which seemed acceptable for panoramic radiography in Yazd, Iran.

Keywords: *Panoramic radiography, surface dose, dose area aroduct, diagnostic reference level.*

INTRODUCTION

Medical diagnostic examinations are the most common source of artificial ionizing irradiation [1,2]. Although for diagnosing and treating patients, ionization radiations are used, their use is not safe due to their side effects and interactions with tissue [3].

The growing availability of radiological systems in developing countries such as Iran has resulted in the increasing number of radiological scans, consequently, population ionizing radiation exposures has increased as well [4]. Therefore, finding the patient's dose in radiographic examinations is one of the essentials step based on ALARA (as low as

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reasonably achievable) principle [5].

Dental radiography is one of the most common radiographs, and panoramic radiography is among the common methods for performing dental radiography [6]. During the panoramic radiography process, sensitive organs including thyroid and parotid glands are exposed directly to radiation which may lead to cancer [7]. Ionization radiation, even in low doses, creates the risk of cancer, especially in young children [8,9]. Due to the longer lifespan of children, the possibility of ionization harmful effects will increase, therefore, children are more sensitive to radiation than adults [10]. For example, the risk of developing leukemia in children is two times higher than adults. Therefore, managing the dose reduction of patients while maintaining image quality is important [11–13].

The International Commission on Radiological Protection (ICRP) has introduced the diagnostic reference levels (DRLs) as a patient dose optimization tool [12]. In publication 135, ICRP recommended the utilization of dose area product (DAP) values as quantities to represent the DRL in panoramic radiography exams [13]. The DAP parameter indicates the amount of radiation emitted in the panoramic radiograph and is typically measured using a DAP meter device. Motivated by the problem mentioned above, it is necessary to extract and use these levels for optimizing the patients' dose in different regions.

Based on our investigation, in Yazd province, there have been 83692 panoramic scans in six high-load institutions in 2019 and this does not seem to be a small or negligible number compared to the population of this province. In addition, due to recent developments in panoramic modalities, it is essential to re-evaluate the patient dose in this technique to have an appropriate justification between the diagnostic value and radiation health risks. Herein, this study was conducted to assess the surface absorbed dose in the thyroid and parotid gland regions as radio-sensitive organs. Furthermore, this paper is the first attempt in Yazd province to establish local DRLs using DAP measurements in panoramic radiography for adults and children groups.

MATERIALS AND METHODS

This cross-sectional study was performed on 7 panoramic radiography systems in 6 of the most crowded hospitals in Yazd province, namely Khatam Clinic, School of Dentistry, Faroukhi, Mehr Emam, Farhangian, and Emam Sadegh from January to December in 2019. The patients were selected randomly from a much larger population. The patients had normal craniofacial morphology (without congenital and acquired facial deformities), and none of the patients had tumor and surgical procedures in their dental region in the past two years.

Data collection

This study was approved by the National Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran, with the ethical number of IR.SSU.MEDICINE.REC.1398.118. In line with the ethical principles of research, written informed consent was obtained from the patients/parents before irradiation

In the present study, 201 patients including 141 adults and 60 children (5-10 years) participated. The adult group consisted of 74 women (53% of the total number) and 67 men (47% of the total number), and in children group, 30 boys and 30 girls took part. The exposure parameters for each patient like applied potential (kVp) and current-time product (mAs) were collected.

The characteristics of the panoramic radiography systems have been described in table 1.

Dose measurement

TLD GR-200 (SDDML, China) chips with the dimensions of 3×3×0.9 mm^3 made of LiF: Mg, Cu, P, with very low detection threshold and almost equivalent to soft tissue in physics characteristics, were used to measure the skin absorbed dose in the parotid and thyroid gland regions. According to the manufacturer's protocol, before and after each application, the TLDs were annealed at 240°C for 10 min and

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then cooled to 35°C. Readouts were performed at 240°C for 10 seconds and pre-heating at 135° C for 5-10 seconds in the TLD reader [15].

Six TLDs on the skin of parotid glands (3 TLDs for each outer ear canal) and 6 TLDs on the skin of thyroid glands (in front of the neck) were positioned for each patient. Furthermore, three TLDs, during the exposures, were fixed on the wall outside the room to determine the background dose for each test. The TLDs were embedded in numbered plastic covers and they were glued to the desired points with leucoplast glue. All TLDs were calibrated for an x-ray exposure according to the approach described by Hasanzadeh *et al.* study [15].

DAP values and DRL calculation

DAP (mGy.cm^2) values were measured by a DAP meter (PTW Diamentor m4, Serial No. 3367, Germany) calibrated in Secondary Standard Dosimetry Laboratory (SSDL). The Barracuda dosimeter (Baracuda, RTI Electronics, Sweden) was used to investigate the accuracy and reproducibility of applied kilovoltage and exposure time for proposes of quality control (QC) for the panoramic radiography systems.

DRL as a standard index used in medical imaging indicates patient absorbed dose in administered radiological procedure to compare different exposure protocols in various institutions and geographical regions. DRLs are a practical tool for optimization of patient dose regarding the image quality. DRLs were first successfully implemented in relation to conventional radiography in the 1980s and subsequently developed for other modalities in the 1990s [16]. In this study, DRL values were determined as the third quartile of the DAP median values for the adults and children based on the ICRP 135 recommendation [13].

Statistical analysis

The measured surface dose values in the parotid and thyroid gland regions resulted from panoramic radiography for adults were compared with pediatric groups in the investigated institutions using non-parametric Wilcoxon statistical test. The statistical analysis was performed with SPSS software (version 16, SPSS Inc, Chicago, IL, USA). P-values lower than 0.05 were considered as a significant difference between the assessed groups.

Table 1. Characteristics of the panoramic equipment.

Institution	Model	Manufacture- country	Year of installation	Serial No	Total filtration (mm Al)	kVp max	Type
A	PM2002C	Planmeca-Finland	2010	KPP 963891	2.5	80	Digital
B	Promax 3D	Planmeca-Finland	2018	KPP 17060157	2.5	84	Digital
C	Promax 3D	Planmeca-Finland	2018	KPP 8N81333	2.5	84	Digital
D	Promax 3D	Planmeca-Finland	2019	KPP 18110225	2.5	84	Digital
E	Ray Scan α-SC	South Korea	2014	PRP 0135818	2.6	100	Digital
F	Soredex	Soredex-Finland	2011	9103723	2.7	85	Digital
G	Promax XC	Planmeca-Finland	2012	RTH 110916	2.5	80	Digital

RESULTS

Table 2 shows the kVp and mAs values for adults and children at different imaging centers. The variation of these values can be related to various scanning protocols used by different institutions.

Surface absorbed dose in the thyroid and parotid gland regions

The TLDs were read by the TLD reader, 24 hours after the exposure. The mean ± SD surface absorbed dose values (μGy) of the thyroid and parotid gland regions for the adult and pediatric groups for each of the panoramic systems are presented in table 3. As it can be seen this table, the highest surface absorbed dose values (average of male and female) for adult patients are 72.7 ± 4.5 and 328.8 ± 10.4 μGy, for thyroid and parotid glands, respectively, belonging to center 'D'. By contrast, the lowest values come from center 'F' with the numbers 41 ± 1.1 and

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196 ± 2.1 µGy, respectively, for those mentioned organs.

For the pediatric participants, the highest values of skin absorbed dose in the thyroid and parotid gland regions are 56 ± 3.5 and 255.2 ± 24.2 µGy, respectively (center 'D'), while, the lowest values are 19.8 ± 1 and 102.8 ± 10.2 µGy (center G). It is notable that in center 'C', no children were admitted for panoramic radiography.

According to table 3, the highest mean value of surface absorbed dose is 290 ± 12.4 µGy, which belongs to the parotid glands in the adult group. In addition, in this group, the mean surface absorbed dose value in the thyroid gland region is 60.6 ± 3.7 µGy. In the children's group, the mean surface absorbed dose value for thyroid and parotid gland regions is 40.7 ± 2 and 189.3 ± 11.5 µGy, respectively.

There was a remarkable difference in the surface dose of thyroid and parotid gland regions in adults compared to pediatric groups ($p < 0.05$), except in center "D" that was not a significant variation in the thyroid surface dose. All in all, the surface dose values in adults were higher.

Table 2. The mean values (±SD) of kVp and mAs for two age groups in panoramic radiography.

Device	Age groups			
	Children		Adult	
	kVp	mAs	kVp	mAs
A	65.4 ± 1	100.8 ± 12.0	66.1 ± 1.0	108.0 ± 5.7
B	63.8 ± 1.5	98.4 ± 23.4	66.4 ± 0.8	128.9 ± 14.0
C	-	-	66.0 ± 0.0	102.6 ± 0.0
D	65.1 ± 1.8	106.1 ± 11	69.1 ± 1.2	142.4 ± 18.0
E	68.6 ± 1.3	79.0 ± 0.0	71.4 ± 1.2	133 ± 5.5
F	57.0 ± 0.0	86.0 ± 0.0	63.0 ± 0.0	110.0 ± 0.0
G	60.0 ± 0.0	48.0 ± 0.0	66.0 ± 0.0	137.0 ± 0.0
Total	63.3 ± 0.9	86.5 ± 7.7	66.8 ± 0.6	123.1 ± 6.2

Table 3. Mean (± SD) skin absorbed dose (µGy) in the thyroid and parotid gland regions for adult and pediatric groups among all panoramic systems and genders. P-values between adult and pediatric groups for both thyroid and parotid glands have been shown.

Panoramic system	Gender	Adult		Pediatric		Comparison	
		Thyroid gland (µGy)	Parotid gland (µGy)	Thyroid gland (µGy)	Parotid gland (µGy)	P-value (adult vs. pediatric)	
						Thyroid gland	Parotid gland
A	Female	58.5 ± 4.6	266.9 ± 28	44.8 ± 3.3	199.1 ± 8	0.01	<0.01
	Male	58.1 ± 3.4	264.2 ± 19	49.2 ± 1.1	213.8 ± 12	0.02	<0.01
	Averaged	58.3 ± 4	265.5 ± 23.5	47 ± 2.2	206.5 ± 10		
B	Female	64.8 ± 6	316.1 ± 14	54.8 ± 1.7	242 ± 3.2	0.03	0.01
	Male	73.8 ± 10	344.7 ± 34	56.2 ± 4.6	250.4 ± 14	0.03	<0.01
	Averaged	69.3 ± 8	330.4 ± 24	55.5 ± 3.1	246.2 ± 8.6		
C	Female	65.3 ± 3	319.1 ± 4.1	-	-		
	Male	66.2 ± 2.7	319.1 ± 4.2	-	-		
	Averaged	65.8 ± 2.85	319.1 ± 4.1	-	-		
D	Female	67 ± 6.7	319 ± 11.2	58 ± 6.4	275 ± 42.2	0.06	0.04
	Male	78.5 ± 2.3	338.6 ± 9.6	53.9 ± 0.6	235.5 ± 6.2	0.04	<0.01
	Averaged	72.7 ± 4.5	328.8 ± 10.4	56 ± 3.5	255.2 ± 24.2		
E	Female	61.2 ± 3.4	309.1 ± 15.1	41.1 ± 2.1	221.4 ± 14.3	0.01	<0.01
	Male	59.5 ± 3.9	301.7 ± 20.6	44 ± 0.6	228.7 ± 0.8	0.02	<0.01
	Averaged	60.3 ± 3.6	305.4 ± 17.8	42.5 ± 1.35	225 ± 7.5		
F	Female	40.9 ± 1.4	195.7 ± 2.8	24 ± 1	101.5 ± 2.9	<0.01	<0.01
	Male	41.2 ± 0.8	196.4 ± 1.5	23.3 ± 1	99.1 ± 2.6	<0.01	<0.01
	Averaged	41 ± 1.1	196 ± 2.1	23.6 ± 1	100.3 ± 2.7		
G	Female	57.6 ± 2.1	287.2 ± 4.6	20.3 ± 1.2	97.4 ± 4.5	<0.01	<0.01
	Male	57 ± 1.2	282.6 ± 6.1	19.4 ± 0.7	108.2 ± 28	<0.01	<0.01
	Averaged	57.3 ± 1.6	284.9 ± 5.3	19.8 ± 1	102.8 ± 10.2		
Total	Female	59.3 ± 3.9	287.5 ± 11.4	40.5 ± 2.6	189.4 ± 12.5	0.03	<0.01
	Male	62 ± 3.5	292.5 ± 13.5	41 ± 1.4	189.2 ± 10.6	0.01	<0.01
	Averaged	60.6 ± 3.7	290 ± 12.4	40.7 ± 2	189.3 ± 11.5		

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DAP and DRL measurements

The tolerances between the DAP meter measurement and systems were lower than 5%. The acceptance level stated by IAEA (international atomic energy agency) is within ± 20%. Therefore, the data from the systems can be used directly for dose measurements.

Table 4 displays the mean ± SD values of DAP (mGy.cm^2) for adult and pediatric participants at all imaging centers. According to the table, the highest value of DAP obtained in the children group was 83.2 ± 14 mGy.cm^2, and that of the adult group was 126.2 ± 2 mGy.cm^2, which belongs to center 'D'. In the adult group, the mean DAP values are 91.2 ± 6.4 which is 1.6 times higher than the children group. In addition, the mean DRL values in terms of DAP for the adult and children groups were obtained as 99.7 and 73.4 mGy.cm^2, respectively.

Table 4. Mean (± SD) values and third quartile of DAP median (mGy.cm^2) as local DRL for the adults and children groups at seven panoramic systems as sex-averaged.

Center / Group	A	B	C	D	E	F	G	Total	Third quartile (DRL)
Children	72 ± 13 (41.8-82.7)	77.7 ± 11.8 (69.2-99.7)	-	83.2 ± 14 (74-107.9)	50.9 ± 1.9 (45-51.5)	27 ± 0 (27)	21.6 ± 0 (21-21.6)	55.4 ± 6.7 (21-107.9)	73.4
Adult	79.8 ± 5.3 (66-99)	103.3 ± 13 (78.5-132.6)	99.7 ± 0 (99-99.7)	126.2 ± 20 (92.9-148)	93.4 ± 7 (79-96.8)	45.1 ± 0 (45-45.1)	91 ± 0 (91)	91.2 ± 6.4 (64-93)	99.7

DISCUSSION

Regarding the side effects of ionization radiation, even small in amounts, it seems to be essential to measure patients' doses during the radiation procedure [17]. Thus, in the present study, we measured the surface absorbed dose in the thyroid and parotid gland regions in panoramic examinations in two age groups of adults and children. In addition, the DRL values were provided using DAP measurements in Yazd province.

The TLDs have used for surface absorbed dose measurements, because they have several advantages such as their tissue-equivalent properties, small size, less sensitivity to changes in radiation energy, reproducibility and lower cost [18].

Our findings revealed that the parotid glands received higher skin doses than the thyroid due to the position of these glands which are completely inside the radiation field during panoramic radiographies. The mean values of surface absorbed dose values (μGy) of parotid and thyroid gland regions compared with the other related studies have been shown in figure 1. It is obvious that the mean skin dose values in the present study are lower than those identified in Lorestan province [19] and Mashhad city [6]. But, these numbers are higher compared to Isfahan [20] and Babol cities [21]. The differences can be related to the use of various exposure factors during the panoramic examinations. However, the results of the thyroid dose in the mentioned parts are a bit different so that the mean skin absorbed dose value for thyroid in Isfahan and Mashhad cities is lower than the present study but it was higher in Lorestan province and Babol city.

It is reported that voltage, tube current, exposure time, filtration, patient size, and collimation are the important factors that affect the DAP values [22,23]. In addition, several investigations have reported that the type of device can affect the dose received of the patients with the same procedure [24,25]. Based on the results, the values of DAP obtained from various panoramic centers are different from one another, and the reason can be related to the above-mentioned factors and different types of panoramic devices investigated in the current study. For instance, the DAP values for the panoramic clinics ranged from 21 to 107.9 mGy.cm^2 for children and 64 to 93 mGy.cm^2 for adult groups. All in all, the surface absorbed dose in the parotid and thyroid gland regions, and also DAP values for the adult patients were higher than those of the children groups,

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probably due the large number of exposure parameters in the adult patients.

According to table 5, the DRL values (mGy.cm^2) in this study are lower than those of Tamil Nedu (114.3 for adults) [26], Korea (151 for adults and 95.5 for children) [27], and Greece (107 for adults and 77 for children) [28]; however, these values were higher compared to Germany (99.7 vs. 85.5 for adults) [29]. The variation in exposure parameters (kVp and mAs) can be considered as crucial factors to cause these differences. In addition, the other factor for these differences can be attributed to the QC of the devices and their types.

In order to reduce the variations of patients' exposures due to arbitrary settings, it seems essential to compile and adjust harmonized imaging protocols in the radiological centers. In addition, implementing the DRLs for reducing the patient dose, increasing the knowledge of health workers, specifically, physicians could improve the justification process.

This study can be considered as the first step in establishing an LDRL for panoramic radiography systems in Yazd province which was performed in the most active institutions. However, it is possible to perform similar studies in other provinces or for other radiography methods for the better understanding and management of public ionizing doses. We hope that this study helps to reduce the public delivered dose by setting up more basic protocols.

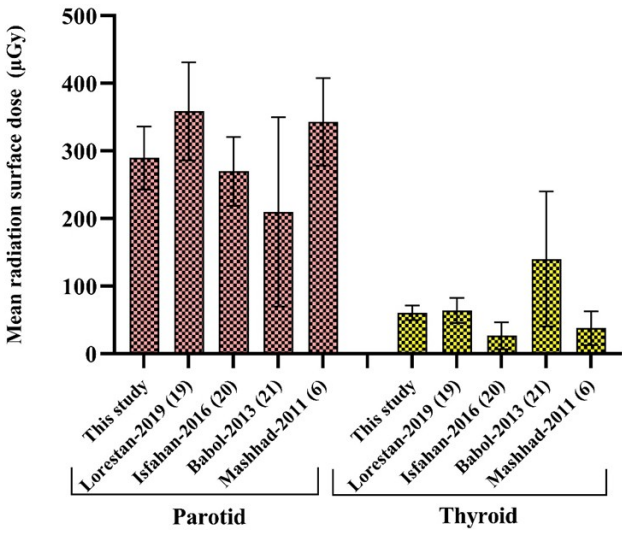

Figure 1. Mean skin absorbed dose (µGy) in the parotid and thyroid gland regions for adult patients compared to the other studies. Error bars define the standard deviations.

Table 5. The 75th percentile values (DRL) based on DAP (mGy.cm^2) values and exposure factors (kVp and mAs).

Center / Group	A	B	C	D	E	F	G	Total	Third quartile (DRL)
Children	72 ± 13 (41.8-82.7)	77.7 ± 11.8 (69.2-99.7)	-	83.2 ± 14 (74-107.9)	50.9 ± 1.9 (45-51.5)	27 ± 0 (27)	21.6 ± 0 (21-21.6)	55.4 ± 6.7 (21-107.9)	73.4
Adult	79.8 ± 5.3 (66-99)	103.3 ± 13 (78.5-132.6)	99.7 ± 0 (99-99.7)	126.2 ± 20 (92.9-148)	93.4 ± 7 (79-96.8)	45.1 ± 0 (45-45.1)	91 ± 0 (91)	91.2 ± 6.4 (64-93)	99.7

CONCLUSION

Owning to the results, the surface absorbed dose values in the thyroid and parotid gland regions were higher in the adult group compared to the children group due to the use of higher radiation parameters. The local DRL proposed in the present work for the adult and pediatric groups was relatively lower than those established by other reports and seemed acceptable for panoramic radiography in Yazd, Iran.

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