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Dose Reduction to the Thyroid Gland in Pediatric Chest Radiography

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Abstract

Background

It is remain a main concern that pediatric chest radiographies contribute to the significant radiation exposure to the thyroid gland as a more susceptible organ to radiation induced cancer. The aim of this study was to evaluate the entrance surface dose (ESD) of pediatric chest radiography compared to the diagnostic reference levels (DRL) and evaluation the efficacy of the lead (Pb) shield in radiation dose reduction to the thyroid gland.

Materials and Methods

After assessing each patient against specific inclusion-exclusion criteria, 40 pediatric patients who were undergoing anterior-posterior (AP) projection of the chest x-ray were considered eligible for this study. The ESD of the chest and also ESD of thyroid gland with and without a 1 mm butterfly-shaped lead shield which placed on the thyroid gland were measured using high sensitive thermo luminescent dosimeters (TLD-GR 200).

Results

The average of ESD for chest radiography was 0.068$\pm$ 0.006 mGy (0.021 - 0.232 mGy). The unshielded average thyroid ESD was 0.065 $\pm$ 0.003 mGy compared to the shielded average thyroid ESD of 0.001 $\pm$ 0.0005 mGy. The use of Pb-shield produced a statistically significant decrease in the average thyroid dose by about 97% ($P< 0.001$).

Conclusion

The use of Pb-thyroid shield in the AP projection of pediatric chest radiography has potential to reduced radiation dose without compromising image quality.

Key Words: Pediatric chest radiography, Radiation exposure, Shield, Thyroid gland.

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1- INTRODUCTION

Ionizing radiations used in medical imaging has probability to establish carcinogenesis (1-3). The cancer risk attributable to medical diagnostic x-rays has been estimated between 0.6% to 3.2% (4). The radiation risk in pediatrics and young children is particularly more concerned than in adults (5, 6). The pediatrics are sensitive to radiation carcinogenesis about 10 times compared to the adults (1). Some pediatrics with chronic disease that periodically receives multiple x-rays, have risk to unacceptable increase of the cumulative dose over the time (1, 5). To reduce such radiation risks, as low as reasonably achievable (ALARA) principle is recommended during the x-ray practices (7). Dose-reducing methods for more frequent x-ray procedures that contribute to substantially collective dose to the population should therefore be regularly investigated, particularly in pediatrics.

Chest radiography is one of the more prevalent x-ray procedures in pediatrics (1, 8, 9). It is estimated that chest radiography contribute quarter of all x-ray examinations (9). It is still remain as a main concern that pediatric chest x-rays contribute to the radiation exposure to the thyroid gland (1, 10). According to Ron et al. (11) “the thyroid gland in children has one of the highest risk coefficients of any organ”. The correlation between high levels of radiation and thyroid cancer, particularly in young children has been well established (11-13). The increasing risk of thyroid cancer from low levels of medical diagnostic x-rays also has been highlighted (14-17). Due to the small size of pediatrics’ body, the chest radiographies are associated with high radiation exposure of non-relevant adjacent organs such as the thyroid gland (10). Moreover, in contrast to the adults, as pediatrics are unable to sit up on their own, their chest radiographs is routinely performed in anterior-posterior (AP) view instead of posterior-anterior (PA) view and consequently their thyroid gland directly are irradiated. Therefore, when imaging of pediatrics, it is essential that the dose is kept in low level as recommended by ALARA.

Shielding is an effective method to reduce radiation exposure to the radiosensitive organs such as the thyroid gland (18). The effectiveness of shielding in pediatric patients has been highlighted (19). Although beam collimation is advocated during pediatric x-rays (1, 20, 21), but collimation dose not entirely eliminate the exposure (5). In addition, as observed in the previous studies (1, 10, 22), when pediatric chest x-ray in clinical practice, thyroid gland is almost always lies in the primary beam. In the previous study, we observed that 100% of infant chest x-rays were included the neck in which thyroid was directly exposed by x-ray (1). In this regard therefore thyroid shielding may be quite effective especially as the low adherence to proper beam collimation during pediatric chest x-rays has been highlighted in the literatures (1, 20).

The certain guidelines for thyroid shielding during pediatric chest x-ray are, unclear and to the best of our knowledge, there is no evidence for the study that evaluated the efficacy of shielding at reducing radiation exposure to the thyroid gland in pediatric chest x-rays. The aim of this study was to assess two issues on pediatric chest radiography: (1) to radiation dose measurements for pediatric chest radiography and comparison with diagnostic reference levels (DRL) and previous studies in order to help in optimizing the chest radiography, and (2) to evaluate the efficacy of lead (Pb)-shield in radioprotection of the thyroid gland.

2- MATERIAL AND METHODS

2-1. X-ray and imaging equipment

All exposures were performed using a Varian x-ray machine (Varian Medical Systems, USA) with a total filtration of 3 mm Al and a focal spot of 1.0 mm^2. Processing of the images was performed using computed radiography system (KONICA MINOLTA, REGIUS model 210).

2-2. Patients

Following the majority of other investigators, after assessing each patient against specific inclusion-exclusion criteria, 40 pediatric patients who were undergoing anterior-posterior (AP) projection of the chest x-ray were selected (6, 19). Patients were considered eligible for inclusion if their ages were 12 months or younger, could cooperate to the requirements of the study and their parents give informed consent. Other patients that did not meet our inclusion criteria were omitted from the study. According to the national (1) and international (22) guidelines [see the **Figures.1** reported by Karami et al. (1) and/or Bader et al.(22)], the exposure field size should cranially be limited to the lower cervical area and caudally to the lower abdominal area at the level of T12/L1 vertebras with maximum variation tolerance of 2 cm in each side.

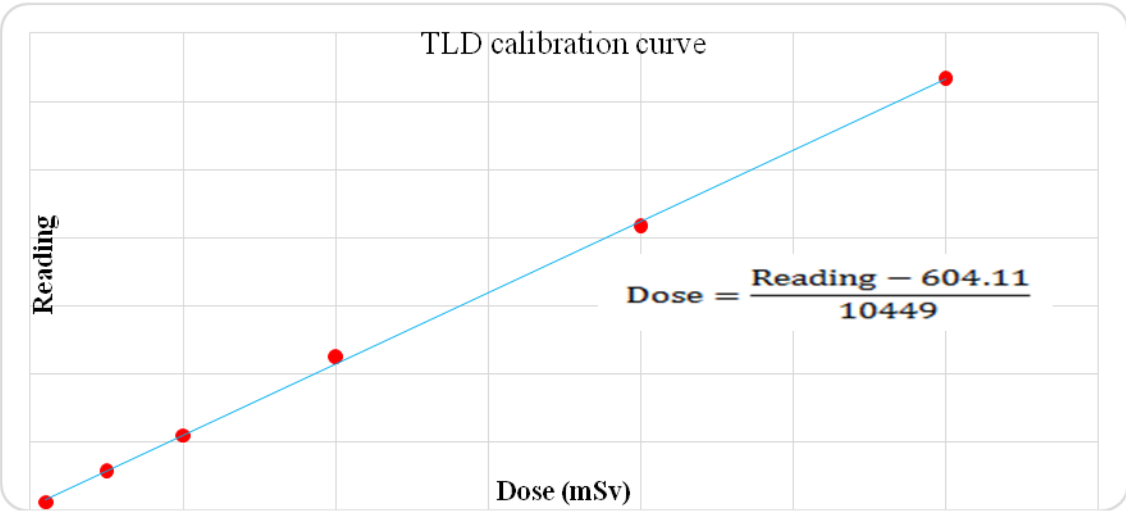

Fig1: TLD calibration curve

2-3. Ethical considerations

The ethical committee of Ahvaz Jundishapur University of Medical Science approved the study protocol (grant No. u94150). The written consent was obtained from the parents before the study.

2-4. Measurements by thermoluminescent dosimeter (TLD)

The high sensitive TLDs (GR-200, LiF: Mg, Cu, P) chips with dimensions of 3.2 × 3.2 × 8.9 mm^3 were used. According to the related protocol, before irradiation, TLDs were annealed at 245˚C for 10 minutes. In order to calibration the TLDs, all used twenty TL chips were exposed three times by a single dose of 50 cGy from Caesium-137 radioactive source at Secondary Standard Dosimetry Laboratory (SSDL) of Karaj, Iran. By knowing of TL efficiency (TLE) of each dosimeter, the element correction coefficients (ECC) of each TL chips were calculated by the following equation 1:

$$(1)\ \mathrm{ECC_i} = \langle TLE \rangle / \mathrm{TLE_i}$$

Where ECC_i is the ECC of a dosimeter i and $<TLE>$ is the mean TLE of all used dosimeters and TLE_i is the TLE of the dosimeter i. More details could be found in literatures (23). The calibration procedure was repeated three times and finally, 18 TL dosimeter chips were selected with calibration constants within ± 2% standard deviation. Six set of three TL chips were independently irradiated by various doses of Caesium-137 radioactive source (0.1, 0.5, 1, 2, 4 and 6 mSv) and two TL chips were considered as control to record the background dose with no irradiation for TLDs calibration.

The TLD calibration curve and its equation were obtained (**Figure.2**). The average of calculated dose from the used TL chips in pediatric chest radiography was calculated and recorded as entrance surface dose (ESD).

2-5. TLD placement

In order to prevent of physical and chemical damages, each TLD chip was placed inside a thin plastic bag when handling. To measure the ESD of chest radiographs, 12 TL chips were placed in different positions of the patient's chest.

A 1mm butterfly-shaped lead shield was provided and placed on the patient's skin exactly where the thyroid gland is located. Eight TL chips were used for thyroid dose measurements for each patient; four of TLDs were placed under lead shield directly where thyroid gland is located (at a point mid-way between the sternal notch and the cricoid cartilage in the midline) and four another TLDs were placed adjacent to the thyroid gland on the patient's skin where with no shield (these four set of TLDs were considered as unshielded thyroid dose, **Figure.2**).

2-6. Statistics analysis

SPSS version 15 was used as statistical tools (IBM Corporation, New York, United States of America). P-value less than 0.001 were considered statistically significant. Comparison of average ESD of the thyroid gland during chest radiography with and without Pb-shielding was made using pair sample t-test.

3- RESULTS

The calculated calibration curve is represented in **Figure.2**. Patients age was under 12 months, the average weight and height of patients were 7.1$\pm$ 2 kg (3.3 - 10) and 66.05$\pm$ 6.3 cm (54 - 75), respectively.

The tube voltage was between 48 and 55 kVp at 3.2, 4 or 5 mAs. The average ESD for chest radiography was 0.068$\pm$0.006 mGy (0.012 - 0.232).

The unshielded average thyroid ESD was 0.065$\pm$0.003 mGy compared with the shielded average thyroid ESD of 0.001$\pm$0.0005 mGy (**Table 1**). The use of Pb-shield produced a statistically significant decrease in the average thyroid dose by about 97% (P < 0.001), without compromising image quality (**Figure.2**).

Table-1: ESD (mGy) values of chest and thyroid gland with and without Pb-shield in pediatric chest radiography

Mean ESD (mGy)				
Chest (with & without)	Unshielded thyroid	Shielded thyroid	Dose reduction %	P-value
0.068	0.065	0.001	97	<0.001

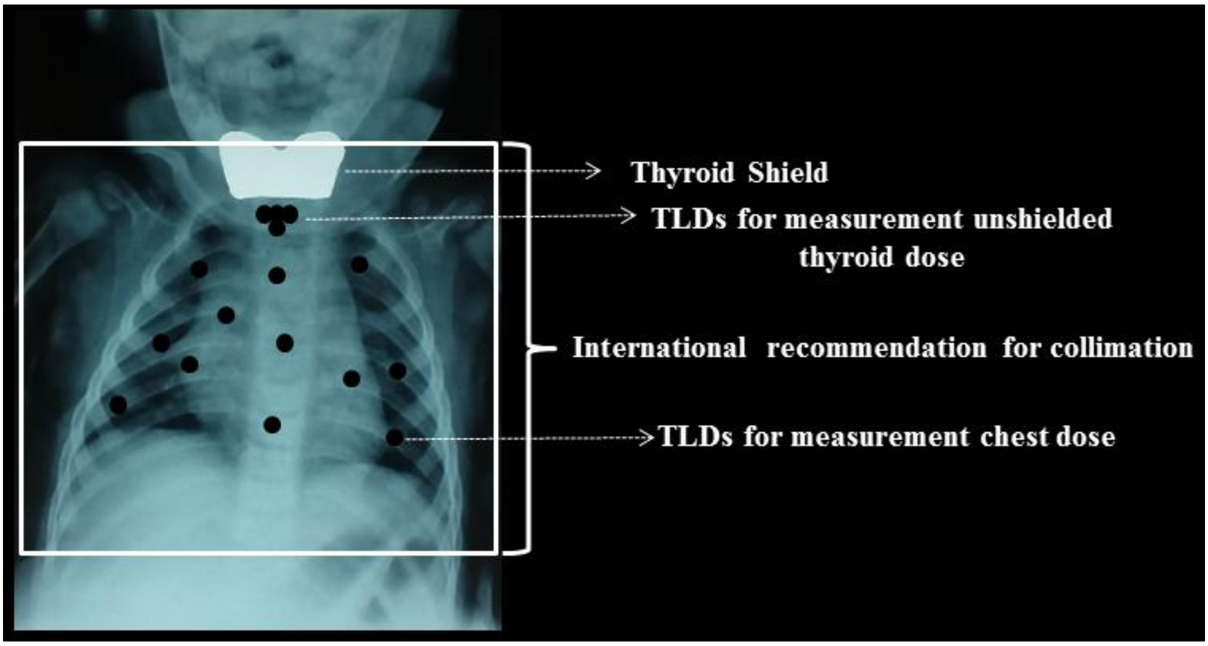

Fig.2: A pediatric chest x-ray with the Pb-shield. The circles are the locations of positioned TLDs. The presence of the Pb- shield has not compromised the image quality. Even by using the international recommendation for the proper beam collimation (shown by white color square), thyroid gland yet directly was irradiated.

4- DISCUSSION

The magnitude of ESDs measured for chest radiography in this study is in relatively good agreement with other studies in pediatrics (**Table.2**), however our data for pediatric are lower than those reported in adults (24-26).

Table.2 shows considerably variations in ESDs for chest radiography in the literatures, due to the ESD values are essentially influence by the patient's characteristics and following the exposure factors. The linear correlation between the ESD and patient's characteristics (weight and height) and kVp has been reported by Osman et al. (2010) (27). **Table.2** also, shows that this study together with seven out of twelve reported ESDs for 0 to 1-year-old pediatric, are lower than the DRL of 0.05 mGy given in the National Radiation Protection Board (NRPB) Report-No. 318 (28). The large variations and the extra ESD values reported in these studies suggest a need to optimization of chest radiography.

Our results showed that using of Pb-shield has statistically decreased the mean ESD of pediatrics' thyroid gland by about 97% (**Table.1**) without compromising image quality (**Figure.3**). This result are consistent with the British standards that state the radiation absorbed dose can be reduce by about 99.4% following to use of 1mm thick, Pb-shield (29). The high radio-sensitivity and superficial location of the thyroid gland makes it an organ of concern during x-ray procedures (14, 30).

Gustafsson et al. (31) investigated the risk of future radiation inducing malignancies due to infant and children chest radiography and highlighted that radiation-induced leukemia and thyroid carcinoma constituted the greatest risk of future malignancies. The radiation dose associate with common radiographic x-ray procedures is very low; and even assuming the linear no-threshold model of dose-response, its risk in an individual patient may not be considerable (32). However, the real concern is due to the cumulative dose and stochastic risks when an individual undergoes multiple and more frequent x-ray exams such as the chest x-ray that is the most frequent x-ray exam throughout the world (27). Eisenberg et al. (2011) (33) and Brenner et al. (2003) (34) showed that multiple procedures in an individual patient can result in a cumulative dose of more than 50 mSv per year that approaches or exceeds the levels which known as increased cancer risk. Radioprotection of the thyroid gland is significant as paralleling the rapid increasing use of medical x-rays in the past decades, the incidence of papillary thyroid cancer is continued to increase (10). Considering the results of this study associate with the recommendations of the National Council on Radiation Protection and Measurements (NCRP) that state: "thyroid shielding shall be provided for children, and should be provided for adults, when it will not interfere with the exam" (35), it is necessary that thyroid gland be adequately shield during pediatric chest x-rays. Although Pb-shield is a valuable protective tool, it should be note that radiographers should make attention in accuracy positioning of the shield without interfering the anatomy of interest. However, it be mentioned that the proper beam collimation as the major contributor to decrease of unnecessary radiation dose to pediatric patients (20, 21), not be neglected. We believe that all referring physicians should also, take responsibility for protection of pediatric patients and when ordering the pediatric chest radiography, write on the request card a reminder to use thyroid shield.

Table-2: Comparing the ESD (mGy) measured in this study with other similar studies in the literatures

Study		Projection	Age (year)	ESD (mGy)	SD	Min	Max
Kepler et al. (36)		AP/PA	<1	0.050	-	-	-
BahreyniToossi et al. (37)		AP	<1	0.076	-	-	-
Makri et al. (38)		AP	<1	0.044	0.016	-	-
Brindhaban et al. (25)		AP	<1	-	-	0.051	0.102
		AP	<1	0.075	-	-	-
BahreyniToossi et al. (39)		AP	1	0.10	-	-	-
		AP	<1	0.06	0.04	0.01	0.27
Kiljunen et al. (40)		PA	<1	0.03	-	-	-
Egbe et al. (41)	C1	AP/PA	<1	0.64	0.15	-	-
	C2	AP/PA	<1	0.07	0.01	-	-
	C3	AP/PA	<1	1.10	0.1	-	-
ICRP 121 (42)		AP	1000 gr newborn	0.05	-	0.01	0.34
This study		AP	<1	0.06	0.04	0.02	0.23

C: center; SD: standard deviation; Min: minimum; Max: maximum.

4-1. Limitations of the study

Firstly, some parents prevent to perform chest radiography by using Pb-thyroid gland shield. Some noncooperation infants to take images without patient motion artifact were replaced by others.

Secondly, standard deviation (SD) of calculated ESD beyond the Pb-thyroid shield is relatively high due to the high attenuation of x-ray beam.

5. CONCLUSION

The Pb-thyroid shield has potential to reduce radiation dose without compromising image quality. The use of thyroid shield during pediatric chest radiography may be an effective method to addressee ALARA, especially for neonatal intensive care unit (NICU) patients who were frequently receiving multiple chest radiography.

6- CONFLICT OF INTEREST: None.

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