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Inadvertent thyroid radiation during Chest CT exam at TASH, Addis Ababa University, Addis Ababa, Ethiopia From July 2018 - January 2019

ADDIS ABABA, ETHIOPIA

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Inadvertent thyroid radiation during Chest CT exam at TASH, Addis Ababa University
Addis Ababa, Ethiopia From July 2018 - January 2019

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Acronym

CT	Computed tomography
AEC	Automatic Exposure Control
Mas	Milliamperage-second
KVp	Kilovoltage peak
MSv	milliSievert
ALARA	As Low As Reasonably Achievable
PTC	Papillary Thyroid Carcinoma
TASH	Tikur Anbessa Specialized Hospital
ICRP	International Commission of Radiological Protection
ED	Effective Dose
DLP	Dose Length Product
CTDIvol	Computed Tomography Dose Index Volume

Operational Definition

Malignancy related (indication): any indication that specifies to look for, characterize and/or stage a primary and to look for secondary involvement of the chest

Summary

Background

The thyroid gland, located between C5 and T1 vertebrae, is a butterfly shaped endocrine gland which is divided into two lobes and connected by an isthmus [1]. Along with the breast, lung and bone marrow, thyroid gland is among the most sensitive organs for radiation due to their rapid cell division [2].

The potential risk factors for thyroid carcinoma development include genetic predisposition, exposure to therapeutic or environmental ionizing radiation, residence in areas of iodine deficiency or excess, history of preexisting benign thyroid disease, as well as hormonal and reproductive factors. [3]

The radiation dose (mGy) towards the thyroid gland is greater during Chest CT as compared to Head CT and Paranasal sinus CT. The association between radiation exposure and the occurrence of thyroid cancer has been well documented, and the two main risk factors for the development of a thyroid cancer are the radiation dose delivered to the thyroid gland and the age at exposure. The risk increases after exposure to a mean dose of more than 0.05-0.1 Gy (50-100mGy). The risk is more important during childhood and decreases with increased age at exposure, being low in adults [4].

Objective

This study is designed to assess the rate of unnecessary radiation exposure to the thyroid gland in patients who presented to radiology department and had Computed Tomography of the chest at Tikur Anbessa Specialized Hospital.

Method

Hospital based retrospective cross-sectional study was conducted on 1306 patients who underwent a chest CT at TASH and thyroid gland inclusion in these studies along with the CT dose of the studies were evaluated over a period of 6 months from July 2018 to January 2019.

Data was collected by evaluating chest CT scans from PACS (Medweb). The data was checked for clarity and completeness. Computerized data analysis was conducted by using SPSS version 24.0 software.

Result

1803 Chest CT scans were done over a period of 6 months out of which, 341 were chest along with another body part (chest + abdomen, chest + head and neck, etc); 83 had missing variables (such as DLP, CTDIvol and/or mean CTDI); 35 had thyroid pathology; 23 scans were done for CT guided biopsy purpose and 15 patients had scans done at least twice within this time frame for which the most latest scan was reported and the others reported as ‘previous CT’s. These data’s, in accordance with the exclusion criteria, were not included.

1306 patient CT scan were included in this study over a period 6 months. Intravenous iodinated contrast media was used in 95.4% of the CT scans. Thyroid was included in 99.8% of the scans, out of which 76.9% included the whole thyroid gland. 12.6% of the patients were scanned previously in addition to the current one. Among the patients who had previous CT scans, 75.3% had one previous scan and 24.7% had two previous scans.

Female had lower scan length compared to male. There was a tendency for linear increment in scan length as age increases. The mean ED was slightly higher than the recommended ED of 5-7mSv with, however, 5% (calculated by conversion factor of ICRP 60) and 7% (ICRP 103) were exposed for higher than the recommended ED (2-20mSv).

1. INTRODUCTION

A computerized tomography (CT) scan combines a series of X-ray images taken from different angles around your body and uses computer processing to create cross-sectional images (slices) of the body. CT scan images provide more-detailed information than plain X-rays do.

Since its introduction in 1972, CT has evolved into an essential diagnostic imaging tool for a continually increasing variety of clinical applications. The original systems were dedicated to head imaging only, but “whole body” systems with larger patient openings became available in the late 1970’s. Technical advancements in developing high-power x-ray tubes and computing technologies led to two major evolutionary leaps in CT imaging during the past decade. The first of these occurred in the early 1990’s with the introduction of CT scanners with simultaneous patient translation and data acquisition (“spiral” or “helical”). The second leap occurred mid-decade, with the introduction of multiple row detectors capable of multiple slices per x-ray tube rotation[5].

CT scan is painless, accurate and fast which is used to see detail of body parts and has largely replaced the “open and see” technique of surgery.

There are differences in organ sensitivity to radiation. For example, the breasts, thyroid, lungs, and bone marrow are more sensitive to radiation because the cells in those areas divide rapidly. Less-sensitive organs include the brain, where cells don’t divide as quickly[2].

The thyroid gland is a butterfly shaped endocrine gland which is divided into two lobes and connected by an isthmus. It is located in the anterior neck, spanning between the C5 and T1 vertebrae.

It lies behind the sternohyoid and sternothyroid muscles, wrapping around the cricoid cartilage and superior tracheal rings. It is inferior to the thyroid cartilage of the larynx. The gland is in the visceral compartment of the neck, along with the trachea, esophagus and pharynx. The compartment is bound by pretracheal fascia[1].

The association between radiation exposure and the occurrence of thyroid cancer has been well documented, and the two main risk factors for the development of a thyroid cancer are the radiation dose delivered to the thyroid gland and the age at exposure. The risk increases after exposure to a mean dose of more than 0.05-0.1 Gy (50-100mGy). The risk is more important during childhood and decreases with increased age at exposure, being low in adults. After exposure, the minimum latency period before the appearance of thyroid cancers is 5 to 10 years [4]. Papillary carcinoma (PTC) is the most frequent form of thyroid carcinoma diagnosed after radiation exposure, with a higher prevalence of the solid subtype in young children with a short latency period and of the classical subtype in cases with a longer latency period after exposure. Molecular alterations, including intra-chromosomal rearrangements, are frequently found. Among them, *PTC* rearrangements are the most frequent. Current research is directed on the mechanism of genetic alterations induced by radiation and on a molecular signature that can identify the origin of thyroid carcinoma after a known or suspected exposure to radiation[4].

2. LITERATURE REVIEW

Chest CT scan Protocol

The process of taking a chest CT involves positioning the patient in supine position with head first on the scanner table and arms raised, placed behind the patient's head, out of the scan plane. Positioning is aided by transaxial coronal and sagittal alignment lights. The median sagittal plane is perpendicular and the coronal plane is parallel to the scanner table top. The scan plane is perpendicular to the long axis of the body to enable that the coronal plane alignment light is at the level of the mid-axillary line. The patient is then moved in to the scanner until the scan reference point is at about 1 inch below the level of chin.

According to the American Association of Physicists (https://aapm.org/pubs/CTProtocols/) the following are the protocols for adult and pediatric Chest CT

Adult Chest CT protocol

Patient Positioning

• Center the patient within the gantry; this is critical for proper functioning of AEC systems.

• Patient supine, arms above head;

Scan Range

• From top of lungs through the bottom of lungs. Instruct patient to hold breath at inspiration during entire scan.

Suspension of Respiration

• Patient should be instructed to hold his/her breath at end of inspiration.

Additional Image Reconstructions

• Certain indications may require that images be reconstructed in coronal and/or sagittal planes.

• Very thin images (approximately = 1 mm) may need to be reconstructed to serve as source images for the sagittal and/or coronal reformatted images.

• Creation, use, and archival of these additional images are at the discretion of the supervising radiologist and/or departmental policy. Very large datasets may result from these additionalreconstructions.

Radiation Dose Management

• AEC should be used whenever possible.
• Pay careful attention to the values selected to define the desired level of image quality (e.g., Noise Index, Quality Reference mAs, Standard Deviation).
• Each manufacturer will have recommendations unique to their systems and system features. Be sure to work with your CT equipment manufacturer and a qualified medicalphysicist to ensure safe and appropriate operation of AEC systems.
• If more than one CT localizer radiograph is acquired, AEC systems from different manufacturers can differ with respect to which one is used to determine mA and/or kV settings. Please refer to individual manufacturer protocol instructions.

Pediatric Chest CT Protocol

Patient Positioning
• Center the patient within the gantry; this is critical for proper functioning of AEC systems.
• Patient supine, arms above head.
• It is common practice to employ a variety of motion-restriction devices (patient safety straps, for example) when working with non-cooperative pediatric patients.

Scan Range
• From top of lungs through the bottom of lungs. Instruct patient to hold breath at inspiration, in cooperative patients, during entire scan.
• Limit the scan range to the anatomy of interest to avoid unintentional exposure of sensitive organs from overrranging.

Suspension of Respiration

• Patient should be instructed to hold his/her breath at end of inspiration in cooperative patients.

Additional Image Reconstructions

• The provided protocols are to be considered as a baseline for CT imaging of the pediatric chest. Additional customization for specific indications may be required.

• Certain indications may require that images be reconstructed in coronal and/or sagittal planes.

• Very thin images (approximately = 1 mm) may need to be reconstructed to serve as source images for the sagittal and/or coronal reformatted images.

• Creation, use, and archival of these additional images are at the discretion of the supervising radiologist and/or departmental policy. Very large datasets may result from these additionalreconstructions.

Radiation Dose Management

• In children, it is especially important to use the lowest dose necessary to achieve the specified diagnostic task.

• AEC should be used whenever possible.

• Reduce tube potential, especially in smaller pediatric patients. The resulting dose reduction is accompanied by an improvement in subject contrast in the image.

• Repeated scans and delayed scans discouraged unless medically indicated.

• Pay careful attention to the values selected to define the desired level of image quality (eg, Noise Index, Quality Reference mAs, Standard Deviation).

• Each manufacturer will have recommendations unique to their systems and system features. Be sure to work with your CT equipment manufacturer and a qualified medical physicist to ensure safe and appropriate operation of AEC systems.

• If more than one CT localizer radiograph is acquired, AEC systems from different manufacturers can differ with respect to which one is used to determine mA and/or kV settings. Please refer to individual manufacturer protocol instructions.

• If iterative reconstruction is available, it should be used as a dose reduction technique when possible, given the underlying indication.

Radiation Dose

The 3 main parameters of radiation dose are absorbed dose, equivalent dose and effective dose. Effective dose is a dosimetry quantity useful for comparing the overall health effects of nonuniform exposure in terms of an equivalent to whole body exposure. It takes into account the absorbed doses received by various organs and tissues and weighs them according to present knowledge of the sensitivity of each organ to radiation. It also accounts for the type of radiation and the potential for each type to inflict biologic damage. The unit of effective dose is the Sievert [6].

A CT scan delivers an effective dose of anywhere from less than 1 to around 10 mSv, depending on the type of scan the patient receives [7]. According to a research done in various hospitals in the Netherlands in 1997 where 3000 CT examinations were obtained in 18 hospitals, the effective dose (which was calculated for each examination using CTDI-to-effective dose conversion factors) showed chest CT was 6-18 mSV which was slightly less than abdominal CT (6-24mSv) but more than brain CT (0.8-5mSv) and lumbar spine CT (2-12mSv) [8]. In another similar study, Chest CT effective dose ranged from 4-18mSv [9].

In a study in 2009, it was found that for routine chest scans, the median effective dose was found to be 8.2 mSv (interquantile range of 5.1 to 11 mSv) [6]. And in 2017 in Nigeria, within a series of institutions, Abuja Clinic, Life Bridge Diagnostic Centre, State House Hospital, Zankli Hospital Abuju, they found the effective dose to be 13.2mSv, 34.0mSv, 9.0mSv and 21.4mSv, respectively [10].

Table 1: CT typical effective dose reference values (mSv)

Parts	Effective dose (mSv)	Mean Reference Effective dose(MRED) (mSv)
Head	1 -2	1.5
Chest	5-7	6.0
Abdomen	5-7	6.0
Pelvic	3-4	3.5
Abdomen & pelvic	8-14	11
Trunk	5-15	10

Diagnostic Procedure	Typical Effective Dose (mSv)[7]
Chest xray (PA film)	0.02
Lumbar spine	1.5
I.V. urogram	3
Upper G.I. exam	6
Barium enema	8
CT head	2
CT chest	7
CT abdomen	8
Coronary artery calcification CT	3
Coronary CT angiogram	16

Thyroid Anatomy

Located deep to the sternothyroid and sternohyoid muscles, the thyroid gland has two lobes which are connected by a staddle in the midline connected by a parenchymal isthmus. The thyroid gland extends cranio-caudally from C5 to T1 and is bordered laterally by the carotid sheaths. The thyroid gland is a well-vascularized structure, having the unique function of concentrating and storing iodine, which is an essential component of thyroid hormone and its metabolites. [11]

Radiation Effect on Thyroid Gland

The worldwide age-standardized incidence of thyroid cancer during the 2–5 yr before 2002 was estimated to be 3.3 and 1.3 per 100,000 for women and men, respectively [12]. In the United States during 2002– 2006, it was 14.2 and 4.9 per 100,000 for women and men, respectively. Thyroid cancer comprises about 2.0% of all malignancies in women and 0.62% in men, and it is one of a small number of cancers for which the incidence is increasing [12]. In the United States between 1980 and 1997, it increased by 2.4% per year, and between 1997 and 2006 it increased by 6.4% per year. Among women, thyroid cancer is the cancer that is rising the most rapidly [12]. Projections for 2009 in the United States are that about 37,200 people (10,000 men and 27,200 women) will be diagnosed, and 1,630 will die of thyroid cancer. For a person born in the United States today, the lifetime risk of developing thyroid cancer is 1 in 119 based on 2004 – 2006 data. It is estimated that about 410,000 people currently living in the United States have been diagnosed with thyroid cancer at some time.[12]

The potential risk factors for thyroid carcinoma development include genetic predisposition, exposure to therapeutic or environmental ionizing radiation, residence in areas of iodine deficiency or excess, history of preexisting benign thyroid disease, as well as hormonal and reproductive factors. [3]

A research done by Baker and Bhatti in 2006 [13] stated that the rapid increase in CT use since 1990 and especially in the past 10 years has been accompanied by a coterminous worldwide increase in incidence of thyroid cancer especially in women. Are the two trends independent or related? Specific information from many countries and seven American states suggest that the relationship is real as no other cause can account fully for the temporal change in the frequency of this malignancy. Moreover, newer techniques of CT performance with or without the administration of iodinated contrast material favor the likelihood of a contingent association of image test utilization and thyroid cancer induction.

In the same research [13] it was found that some patients, who underwent myelography with fat-soluble iodinated contrast material had enhancement damage years later. Even after the study was done, not all of the contrast could be removed. Hence, it stayed in the patient as an iodine sump, which eventually and gradually entered into the general circulation to accumulate in the thyroid gland. Then if these patients later underwent head and neck therapeutic radiation, they experienced a higher incidence of hypothyroidism because of the damage inflicted by radiation beam as it encountered the iodine-laden gland.

A survey of physicians of the American Society of Emergency Radiology revealed that 61% of respondents included the thyroid gland as part of the coincident CT studies of the cervical spine and the chest in trauma protocols [14]. There is increasing concern regarding radiation exposure to the thyroid gland from pediatric CT scans. Over a 10-yr span, from 1996 to 2005, at one large academic institution the fraction of multiregion CT scans in children increased from 4.9% to 7.8%, likely increasing the radiation dose to the thyroid[15]. If multiphase CT examinations are performed, the dose is increased even more. Additionally, the use of iodinated contrast with CT increases the radiation absorbed by the thyroid by up to 35% [16].

Mathews et al [12] compared cancer incidence in children aged 0 to 19 years exposed to CT scans between 1985 and 2005 with incidence in the corresponding unexposed population. The overall incidence of cancer was found to be 24% higher in the exposed group than in the unexposed group; risk increased with dose and with younger age at exposure. The rates of both solid and nonsolid tumors increased.

Chest CT scans caused higher thyroid dose and the LAR (Lifetime Attributable Risk) of thyroid cancer incidence, compared with paranasal sinus or head CT scans. Therefore, physicians should pay more attention to protect the thyroid when children underwent CT scans, especially chest CT scans [17].

Radiation dose (mGy) in the thyroid, by age, using the three CT protocols. **[17]**

CT protocol	Age (years) at Scan			
	0	1–<5	5–<10	10–15
Paranasal sinus CT	-	0.92	0.65	0.61
Head CT	2.45	1.82	1.38	1.10
Chest CT	5.76	4.34	3.50	2.63

Radiation Protection

ALARA is a safety principle designed to minimize radiation doses and releases of radioactive materials. More than merely best practice, ALARA is predicated on legal dose limits for regulatory compliance, and is a requirement for all radiation safety programs.

1. TIME—Minimize the time of exposure.
2. DISTANCE—Double the distance between your body and the radiation source; this reduces the radiation exposure by a factor of 4.
3. SHIELDING—Use absorber materials such as Plexiglas® for beta particles and lead for X-rays and gamma rays.

In a study done [18], on average, shielding resulted in a 47% organ-dose reduction for the thyroid and 32% for the breast. Placement of the spacer between shield and surface had no significant impact on the measured doses, but significantly decreased the image noise (Pv0.05). So in conclusion, in-plane bismuth breast and thyroid shielding significantly decreases radiation dose in MDCT without deteriorating image quality

3. OBJECTIVES

3.1. General objective

- To assess the rate of unnecessary radiation exposure to the thyroid glands
- To assess the effective dose value in Chest CT scan in our institution

3.2. Specific objectives

- To investigate the average number of chest CT scans which include the thyroid gland
- To assess whether thyroid gland radiation exposure is avoidable during chest CT
- To suggest ways of reducing radiation exposure to the thyroid glands
- To investigate DLP and CTDIvol of chest CT and compare ED with other published values

4. METHODS AND MATERIALS

4.1 Study area and period

The study is conducted at TASH, College of health science, Addis Ababa University, Addis Ababa Ethiopia. TASH, located in the nation's capital, Addis Ababa, is a largest referral as well as a main teaching hospital. The hospital provides a tertiary level referral treatment with over 900 beds and is open 24hrs for emergency services.

The study was conducted from July 2018 -January, 2019 G.C.

4.2 Study design

A retrospective cross sectional study was employed.

4.3 Population

4.3.1 Source population

The source population will be all patients who had chest CT during the study period.

4.3.2 Study population

This is a retrospective study which includes a total number of 1306 patients that were referred to the Radiology Department – TASH to do Chest CT scan during the period from July 2018 to January 2019.

4.3.3 Inclusion and exclusion criteria

4.3.3.1 Inclusion criteria

- All patients evaluated with chest CT

4.3.3.2 Exclusion criteria

- Patients who have multiple region scan (eg. Chest with abdominopelvic CTscan)
- Patient who had previous thyroid surgery
- Patients who underwent CT scan to evaluate the thyroid gland
- Patients who have missing dose variables (DLP, CTDIvol and/or mean CTDI)
- CT images done for CT guided chest biopsy

4.4 Sampling technique and sample size

All patients with Chest CT who have fulfilled the inclusion criteria during the study period were included in the study.

4.5 Data collection plan

Data was collected using structured questionnaire from Picture Archive Communication System (MedWeb). Patients' image was reviewed and the presence of thyroid gland (along with other information such as type of CT and previous imaging) and CT dose information (CTDIvol, scanning length, DLP) was assessed. The CT reports were reviewed and findings recorded in the questionnaires.

4.6 Data quality control

In order to evaluate the clarity of the findings, unclear images were evaluated with colleagues.

4.7 Data analysis and interpretation

The data was checked for clarity and completeness. Data was analyzed using nonparametric statistical methods with the help of SPSS version 24.0 software package. Then summarization and comparison of data was done.

4.8 Ethical considerations

In order to respect patient's bill of right, ethical considerations was taken into account. This is a retrospective study where patient identifiers was not used in the data collection or analysis. Any piece of information was kept confidential by keeping anonymity of the study subjects.

4.9 Limitations

- Lack of MedWeb images prior to April 24, 2017 (when the system was initiated) to evaluate previous images of patients'
- Inability to access previous CT images taken at other facilities (other than TASH)

4.10 Plan of disseminating study finding

After the formal preparation of the final report the copy of the report was submitted for evaluation, and possible future publication.

5. RESULT

1803 CT scan were done over a period of 6 months out of which, 341 were chest along with another body part (chest + abdomen, chest + head and neck, etc); 83 had missing variables (such as DLP, CTDIvol and/or mean CTDI); 35 had thyroid pathology; 23 scans were done for CT guided biopsy purpose and 15 patients had scans done at least twice within this time frame for which the most latest scan was reported and the others reported as 'previous CT's. These data's, in accordance with the exclusion criteria, were not included.

A total of 1306 patients were included in this study. The age distribution was approximately a normal distribution with skewness of -0.054. The mean age was 41.7 years (SD ±18.6). Age categorization showed most (89.9%) were adults (age >18 years). Male and female proportion was comparable with male accounting for 48.9% of the total.

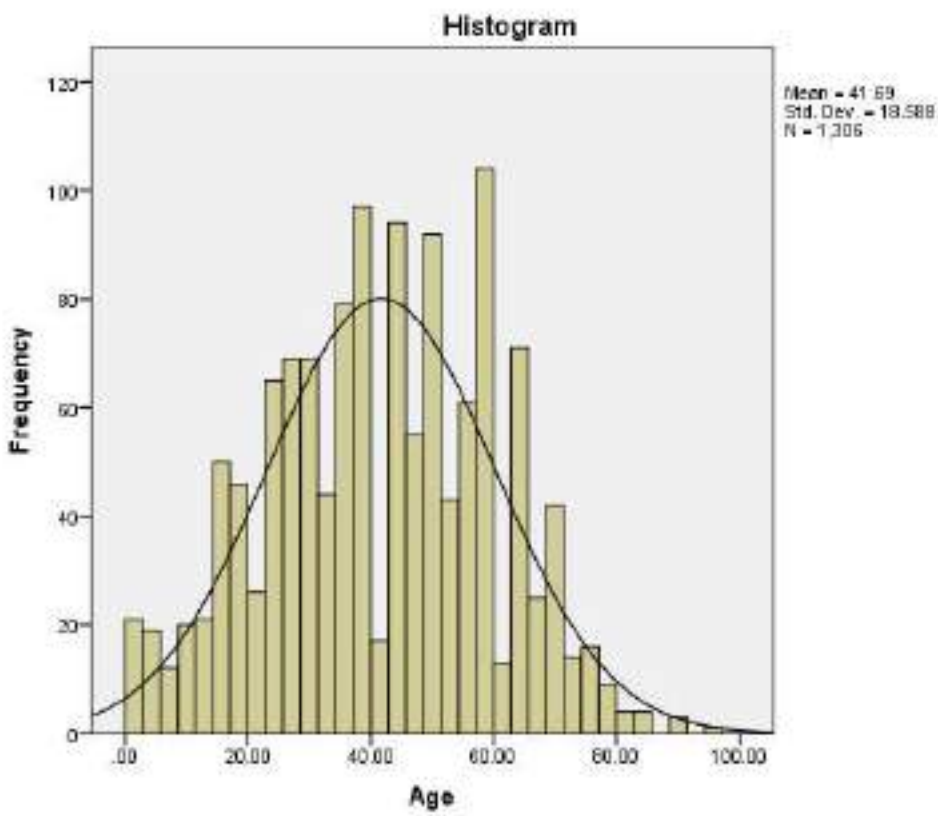

Figure 1: Age distribution

Table 2: Background characteristics of the patients			
		N	%
Age	<1yr	6	0.5%
	1-5yr	27	2.1%
	5-10yr	24	1.8%
	10-18yr	86	6.6%
	>18yrs	1163	89.1%
Sex	Male	638	48.9%
	Female	668	51.1%
Clinical symptoms	Malignancy related	778	59.6%
	Cough	225	17.2%
	Fever	79	6.0%
	Hemoptysis	44	3.4%
	Chest Pain	67	5.1%

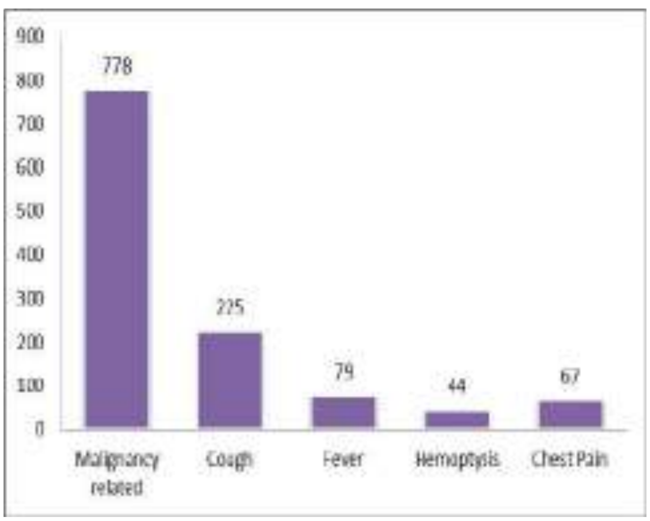

Figure 2: Indication CT scan

Figure 3: Distribution of sex among the patients

Intravenous iodinated contrast media was used in 95.4% of the CT scans, with 60.7% being post contrast only and the rest 34.7% had both pre and post contrast CT scan. Except in two patients, thyroid was included in all of the remaining patients (99.8%). The whole thyroid gland was involved in 76.9% of patients, as evidenced by visualization of upper lobe of thyroid gland.

Table 3. Type of CT scan and involvement of thyroid gland

		N	%
Type of CT	Precontrast	60	4.6%
	Post Contrast	793	60.7%
	Both	453	34.7%
Thyroid included	Yes	1304	99.8%
	No	2	0.2%
Proximal end of Thyroid seen	Yes	1001	76.9%
	No	301	23.1%
Incidental Finding	Yes	312	24.0%
	No	989	76.0%

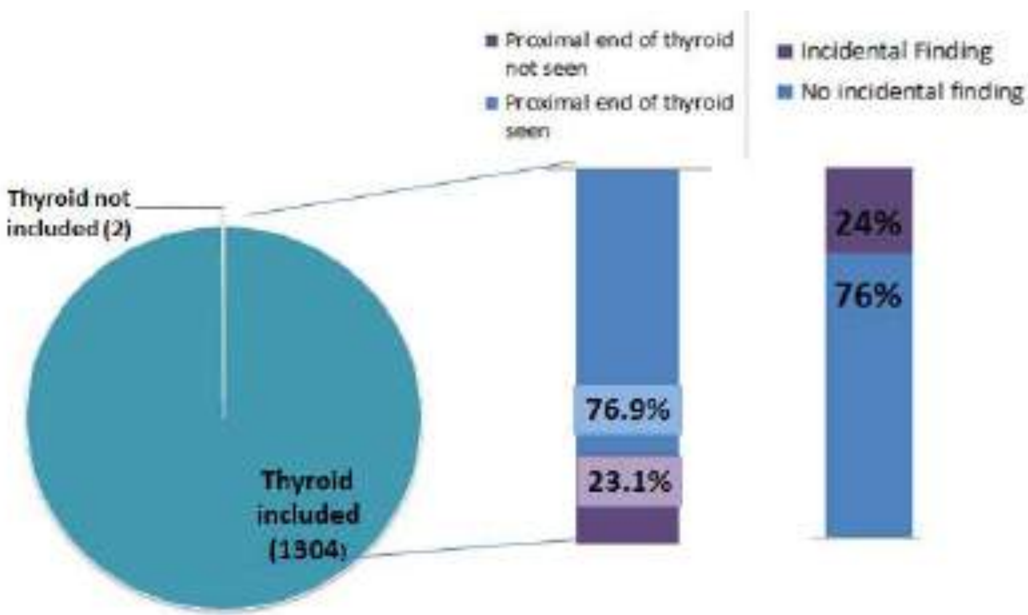

Figure 4: Rate of Thyroid Involvement and Incidental Finding

12.6% of the patients had one or more previous CT scans, with 75.3% having one previous CT scan and 24.7% having two or more previous CT scans. Similar to the current CT scan, 95% of the previous CT were contrast enhanced, thyroid was involved in 98.7% of the previous scans, with 69.9% involving the whole thyroid gland.

Table 4. Number of previous CT scans and thyroid involvement			
Had previous CT	Yes	164	12.6%
	No	1140	87.4%
Type of Previous CT	Precontrast	8	5.1%
	Post Contrast	104	66.7%
	Both	44	28.2%
Thyroid included in Previous CT	Yes	151	98.7%
	No	2	1.3%
Proximal end of thyroid seen	Yes	107	69.9%
	No	46	30.1%
How many previous CT	1	119	75.3%
	≥2	39	24.7%

The overall mean scan length of the patients was 40cm (SD±59.2). The correlation of scan length with age and sex was assessed. The person's correlation coefficient for age was 0.33 and for sex was -0.12. This indicates that the correlation of scan length with age and sex was weak; as age increases scan length will increase and female have lower scan length than male. Age was also classified in different categories and the respective mean scan length in each age category was done by using ONE WAY ANOVA (analysis of variance).

Table 5. Correlation of scan length with age						
Scan Length (mm)						
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
<1yr	6	176.4567	51.37629	20.97428	122.5406	230.3728
1-5yr	27	212.9830	59.33890	11.41978	189.5093	236.4567
5-10yr	24	289.4408	71.80378	14.65688	259.1208	319.7609
10-18yr	86	363.6606	67.31444	7.25870	349.2283	378.0928
>18yrs	1163	410.9623	43.25053	1.26824	408.4740	413.4506

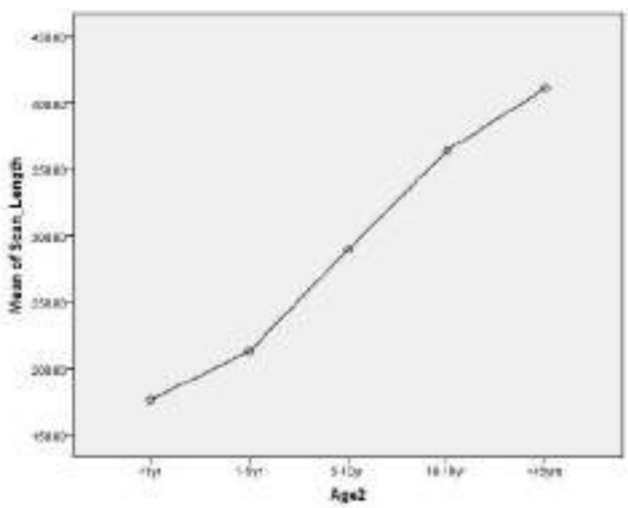

Figure 5: Relationship of Scan Length with age

The overall mean of CTDIvol were 7.5 and 392.6 respectively. The mean distribution of each of these variables according to different sex and age categories was done by using ONE WAY ANOVA and independent sample t-test. The result is presented in the table below.

Table 6. The mean values of scan length, CTDIvol, and DLP		
	Mean	SD
Scan Length	40	59.2
Mean CTDIvol	7.5	5.8
DLP	392.6	355.6

Table 7. Mean distributions of scan length, CTDIvol and DLP in age and sex categories

		Scan Length (mm)		Mean CTDIvol (mGy)		DLP (mGy)	
		Mean	SD	Mean	SD	Mean	SD
Sex	Male	407.49	61.83	7.89	4.74	426.45	378.44
	Female	393.72	55.78	7.09	6.67	360.33	329.38
Age	<1yr	176.46	51.38	5.52	1.36	295.04	414.20
	1-5yr	212.98	59.34	5.48	1.68	146.83	103.86
	5-10yr	289.44	71.80	6.49	3.24	228.22	163.50
	10-18yr	363.66	67.31	4.43	2.36	175.24	129.44
	>18yrs	410.96	43.25	7.78	6.04	418.31	364.84

The mean DLP was 392.5 with SD of 355.6. DLP was lower in female compared to male. The mean DLP among male was 426.45 and among female it was 360.33; this difference was statistically significant with mean difference of 134. The effect of sex on DLP is because of lower scan length in female compared to male as described above. The lowest DLP value was observed in the pediatric patients in the age range of 1-5 years which was 103.86, while the highest was observed among those below 1-year-old with mean DLP of 414.2 in this age group. Among the variables, CTDIvol was the parameter that was strongly correlated with DLP value, with Pearson correlation coefficient of 0.54. An increase in CTDIvol by one unit will increase the DLP by almost 32 times (95% CI 30.15-35.41). The variables scan length, age, and sex; even though were associated with DLP value, they were weakly correlated with DLP value and had poor estimation power as evidenced by very low correlation coefficient, larger SE and wider confidence intervals.

Table 8. Multivariate Linear logistic regression of variables with DLP							
	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-148.048	60.194		-2.460	.014	-266.135	-29.961
Scan Length	.475	.137	.079	3.468	.001	.206	.743
Mean CTDIvol	**32.780**	**1.338**	**.537**	**24.491**	**.000**	**30.154**	**35.406**
Age	4.084	.446	.213	9.155	.000	3.209	4.959
Sex	-42.948	15.345	-.060	-2.799	.005	-73.052	-12.844

The estimated mean effective dose of chest CT scan when the chest (60 ICRP) conversion factor is used was 7.44msv (SD ±6.9) with 26.2% being exposed for radiation ED of above 9msv and 5% received ED above 20msv. When the conversion factor chest (103 ICRP) is used, the mean ED was 8.66msv (SD ±8) and the proportion of patients exposed to ED higher than 9msv and 20msv were 34.3% and 7%, respectively.

Table 9: Mean ED (Effective Dose)				
	Mean	Standard Deviation	Minimum	Maximum
ED (60)	7.44	6.92	.63	101.23
ED (103)	8.66	8.03	.71	118.10

	Table 10: ED Distribution							
	<9		9-20		20-50		>/50	
	Count	%	Count	%	Count	%	Count	%
ED60	964	73.8%	276	21.1%	63	4.8%	3	0.2%
ED103	856	65.7%	356	27.3%	87	6.7%	4	0.3%

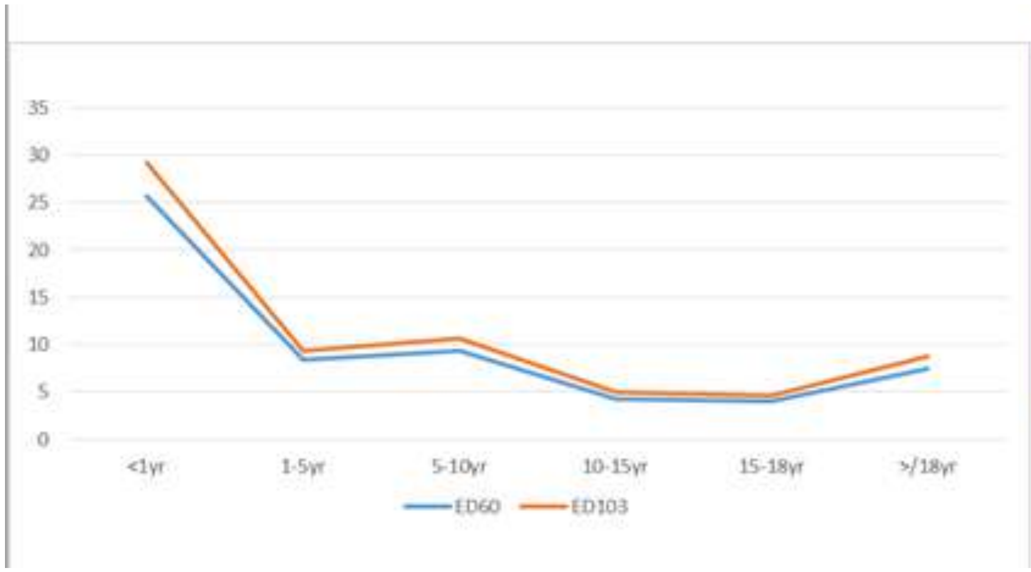

Figure 6 : Comparison of age with ED with ICRP 60 and 103

Table 11: ED (effective dose) according to ICRP 60							
ED (60)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
<1yr	6	25.6683	36.03550	-12.1486	63.4853	8.11	99.09
1-5yr	27	8.3691	5.91979	6.0273	10.7109	.63	22.77
5-10yr	24	9.3572	6.70369	6.5264	12.1879	2.51	30.50
10-15yr	36	4.3134	3.49735	3.1301	5.4967	1.86	21.18
15-18yrs	50	4.0003	2.76620	3.2141	4.7864	1.04	21.06
>/18yrs	1163	7.5296	6.56716	7.1518	7.9074	.75	101.23
Total	1306	7.4401	6.91563	7.0647	7.8155	.63	101.23

Table 12: ED (Effective Dose) according to ICRP 103

ED(103)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
<1yr	6	29.2088	41.00591	-13.8243	72.2419	9.22	112.76
1-5yr	27	9.3969	6.64678	6.7675	12.0263	.71	25.56
5-10yr	24	10.7265	7.68472	7.4815	13.9715	2.88	34.96
10-15yr	36	5.0837	4.12188	3.6890	6.4783	2.19	24.96
15-18yrs	50	4.5717	3.16138	3.6733	5.4702	1.19	24.07
>/18yrs	1163	8.7845	7.66169	8.3437	9.2253	.88	118.10
Total	1306	8.6634	8.03130	8.2274	9.0994	.71	118.10

The value of ED was significantly and independently associated with mean CTDIvol, scan length, and age of the patient. While, sex of the patient was not associated with the amount of ED. The amount of the mean CTDIvol was the main determinant factor for the observed variation in the amount of ED.

Among the age groups, the highest ED was given for children in the age range of below one year followed by children in the age range of one to ten years. The lowest ED was given for adolescents in the age range of ten to eighteen years.

The age of the patient is a fixed variable, however, by changing the other parameters, the ED can be decreased in younger children. The scan length should also be selected appropriately based on the diagnostic information that is required. Since the mean CTDIvol was the most determinant factor for variation in the observed ED, technicians should adjust the parameters that in turn determine the amount of the CTDIvol, such as the KV.

Table 13: Determinant factors for Effective Dose

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	Mean_CTDIvol	.786	.032	.630	24.610	.000	.723	.848
	Scan_Length	.027	.004	.936	7.438	.000	.020	.035
	Sex	.149	.353	.020	.422	.673	-.544	.842
	AGE_NEW	-1.476	.282	-.725	-5.228	.000	-2.029	-.922

6. DISCUSSION

Out of the 1306 patient with Chest CT (95.4% having post contrast studies), thyroid gland was included in 99.8% of the scans with 76.9% having whole of the thyroid included. 12.6% of the patients were scanned previously in addition to the current one, out of which thyroid was included in 98.7% with 69.9% having proximal end visualized.

The strongest determinant of DLP value was the mean CTDIvol. Although scanning length had increment with sex and age, our study showed that the later correlation is not strong enough and that females had lower scan length compared to male.
Although the mean ED (using both ICRP 60 and 103) was within the interquantile range of 5.1 to 11 mSv [6] i.e (7.44mSv and 8.66mSv respectively) it was shown that 5% and 7% had ED greater than 20mSv which is higher than effective dose found in a study done which showed a range of 6-18 mSV [8].

Since its introduction, CT scan has become one of the essential diagnostic tools in clinical practice. The increasing utilization of CT scan also created concerns related with potential radiation associated damages. The risk of tissue damage from exposure to radiation is assumed to increase with increasing radiation dose.

In addition to radiation dose, the risk of radiation injury is also affected by organ sensitivity and age of the patient with risk being higher in children compared to adults. A study evaluating patient and organ doses in pediatric and adult chest examinations demonstrated that for each CT scan the thyroid doses depended on the scanner and protocol used and for children and adults were up to 21 and 20 mGy, respectively (16). As a result of this concept, various society guidelines issued recommendations on the need to ascertain a clear indication for CT scan and when used to use lowest possible dose.

Thyroid is one of the organs which are sensitive to radiation exposure. The association of radiation exposure with thyroid cancer was described in different literatures. Thyroid cancer comprises about 2.0% of all malignancies in women and 0.62% in men, and it is one of a small number of cancers for which the incidence is increasing [12]. In the United States between 1980 and 1997, it increased by 2.4% per year, and between 1997 and 2006 it increased by 6.4% per year. Among women, thyroid cancer is the cancer that is rising the most rapidly (8). Apart from radiation exposure from increasing utilization of diagnostic imaging such as CT scan, no other factor could be identified that can explain the increasing incidence of thyroid cancer.

The thyroid gland is located in the anterior neck and spans from C5 to T1, and the apex of the lung is at T1 vertebral level (7). This anatomic proximity of thyroid and lungs may put the thyroid gland for inadvertent radiation exposure during chest CT scan. The optimal procedure for chest CT scan is recommended to include the tops and bottoms of the lung. In our study, the whole thyroid was involved in 76.9% of the chest CT scans. This is much higher than the apex of the lungs at T1 and indicates inadvertent exposure of thyroid for excess radiation. This extra exposure increases the total radiation dose received by the patent and has implication to radiation related injuries in other organ systems in addition to the thyroid gland.

In addition, 95.6% of the scans utilized iodinated contrast media which further increases the risk of radiation associated toxicities. A study showed that the use of iodinated contrast with CT increases the radiation absorbed by the thyroid by up to 35% [16].

In a study done by Stephen et.al on CT scans done in trauma series, the concern for inadvertent exposure of the thyroid was reported. In this study, a double exposure to the bystander thyroid gland was observed in 83% of the scans from cervical and chest CT that were done as part of trauma series. The study concluded on the need to find alternative strategies to avoid such unnecessary exposures of the thyroid.

Unlike x-ray, the appearance of CT imaging doesn’t help to estimate the possibility of excess radiation exposure. In fact, the quality of CT imaging will improve as the dose of radiation is increased. There will always be a tradeoff between the quality of the image and the risk of radiation. It is the responsibility of the radiologist and radiographer to decide the imaging protocol that should be used in a particular disease and patient conditions with the aim of achieving the required diagnostic information by using the minimum possible radiation dose (ALARA principle).

So, what can be done to decrease radiation induced damage to the thyroid? A study done in 2011 at Duke University using MOSFET (metal oxide semiconductor field effect transistor) showed that thyroid radiation dose decreased by 28%, 33%, and 45% by organ-based dose modulation, automatic tube current modulation with thyroid shield, and organ-based dose modulation with thyroid shield protocols, respectively, compared with the use of automatic tube current modulation alone ($p \leq 0.005$) [19]. In addition, decrement of dose was also found to be effective. That is, excess thyroid cancer mortality per 100,000 patients for both standard (26.0 mGy) and low-dose CT protocols (14.1 mGy) was assessed and showed a 50% decrement of mortality from thyroid cancer [20].

7. CONCLUSION

1306 patient CT scan were included in this study over a period 6 months. Intravenous iodinated contrast media was used in 95.4% of the CT scans. Thyroid was included in 99.8% of the scans, out of which 76.9% included the whole thyroid gland. The apex of the lung is located about T1 cervical level and thyroid gland spans from C5 to T1. Involvement of the lower end of thyroid may be unavoidable, but involvement of the upper end of thyroid is unjustifiable and indicates an unnecessary radiation exposure to the thyroid gland. 12.6% of the patients were scanned previously in addition to the current one. Among the patients who had previous CT scans, 75.3% had one previous scan and 24.7% had two previous scans. The pattern of thyroid involvement in previous scans was similar to that of the current CT scan. Almost all of these scans were done within one-year period from the current CT scan. As the number of CT scan increases, the cumulative radiation dose and the risk associated with radiation exposure to the thyroid and other organs will increase. Although we cannot assess, whether repeat scan were justifiable or not, the dose received by the patient will be higher with any additional CT scan done regardless of its benefits.

Female had lower scan length compared to male. There was a tendency for linear increment in scan length as age increases. However, age was not a good predictor of scan length. As the DLP is derived in part from scan length, the effect of age on scan length was minimal. The strongest determinant of DLP value was the mean CTDIvol. This is the dose parameter that is independent of patient characteristics, but that can be adjusted on the machine. The mean ED (calculated with ICRP 60 and 103) was within the range of the recommended limits for chest CT scan, however, 5% and 7%, respectively, were exposed for higher than the recommended (>20mSv) ED. In addition, the recommended ranges for ED is derived from a different reference population for adult weight of 65-70kg, which may underestimate the ED in our patients'.

Annex

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Questionnaire

	Card No:	
1.	Sex:	1. Male: 2. Female:
2.	Age:	
3.	Date of CTscan (DD/MM/YR):	
4.	Clinical Indication (circle if more than one):	1. Malignancy related 2. Cough 3. Fever 4. Hemoptysis 5. Chest pain 6. Other ____
5.	Type of CTscan?	1. Pre contrast 2. Post contrast 3. Both
6.	Thyroid Included	1. Yes 2. No
7.	Is the whole of the thyroid lobe included? (proximal end is seen)	1. Yes 2. No
8.	Any incidental pathology seen in the thyroid?	1. Yes 2. No
9.	Amount of CT Dose Length Product, DLP (in mGy) (DLP)	
10.	Mean CTDIvol (in mGy)	
11.	Scanning Length (in mm)	
12.	Did patient have another Chest CTscan previously?	1. Yes 2. No
13.	If yes, how many times?___	1. 1 2. ≥2 times
14.	If yes, when? (DD/MM/YR) (please specify each date if more than one)	
15.	If yes, type of previous study	1. Pre contrast 2. Post contrast 3. Both
16.	Was thyroid included in the other study(ies)?	1. Yes, in ≥1 2. No
17.	Is the whole of the thyroid lobe included?	1. Yes, in ≥1 2. No
18.	Is there a cervical rib?	1. Yes 2. No
19.	If so, please specify where	1. Left 2. Right 3. Bilateral

Scan region	0-y-old		1-y-old		5-y-old		10-y-old		15-y-old		Adult	
	Head	Body	Head	Body	Head	Body	Head	Body	Head	Body	Head	Body
Head and neck	0.014		0.009		0.007		0.005		0.004		0.003	
Head	0.009		0.006		0.004		0.003		0.002		0.002	
Neck	0.023		0.013		0.009		0.007		0.005		0.005	
Chest (103)	0.051	0.099	0.033	0.064	0.024	0.047	0.017	0.033	0.012	0.024	0.011	0.021
Chest (60)	0.045	0.087	0.029	0.057	0.021	0.041	0.015	0.028	0.011	0.021	0.009	0.018
AP	0.047	0.092	0.031	0.060	0.022	0.043	0.014	0.028	0.011	0.022	0.009	0.018
CAP	0.044	0.086	0.029	0.056	0.021	0.041	0.014	0.028	0.011	0.021	0.009	0.018
Abdomen	0.045	0.088	0.032	0.063	0.022	0.043	0.017	0.032	0.014	0.027	0.011	0.022
Pelvis (103)	0.028	0.054	0.021	0.041	0.015	0.028	0.009	0.017	0.008	0.015	0.006	0.011
Pelvis (60)	0.036	0.069	0.027	0.053	0.019	0.038	0.012	0.023	0.010	0.020	0.007	0.014

Table: Age-specific k-factors (mSv mGy21 cm21) for 0-, 1-, 5-, 10- and 15-y-old, and adult ICRP reference phantoms for eight different scan types based on head and body CTDI phantoms. For the chest and pelvis scans where the effective doses based on the ICRP 60 and 103 tissue weighting factors are significantly different, 60 and 103 were added in the parenthesis for the scan types. The k-factors for other scan types are based on ICRP 103 [21].

Proposed European commission reference dose levels for routine computed tomography examinations on the basis of absorbed dose in air [22]

Examination	$CTDI_{vol}$ (mGy)	DLP (mGy_{air} cm)
Head	60	1050
Chest	30	650
Abdomen	35	780
Pelvis	35	570

CTDIvol – Computed tomography dose index; DLP – Dose length product