Evaluation of Radiation Dose to Skin overlying Thyroid during Mammography X-Ray Examination at a Selected Hospital.

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Abstract: The aim of the study was to evaluate the radiation dose to skin overlying thyroid during mammography. This was an observational descriptive study carried out using mammography equipment in a private medical institute in Sri Lanka. Consequently, 75 patients were recruited for the study. Data were collected using a constructive data sheet. Total accumulated radiation dose to skin overlying the thyroid was measured for each mammography projection in each patient by placing an electronic pocket dosimeter at the level of the palpable thyroid cartilage. The mammography projection, thickness of the compressed breast and the distance between the breast and skin overlying thyroid after applying the compression were measured. mAs and kVp also were recorded. Mean age of the patients were 51 (±11) years and among 75 patients 80% were referred to diagnostic mammogram while 20% were referred to screening mammogram. Accumulated Equivalent Radiation dose (AED) received by the skin overlying the thyroid in CC projection was within 2.6452µGy to 3.8446µGy. The average radiation dose received by the skin overlying thyroid in MLO projection was within 5.7468µGy to 8.1924µGy. During a routine mammographic examination total equivalent radiation dose of 20.4290µGy was received to skin overlying the thyroid gland. It was also found that recorded mAs, kVp, and measured breast thickness each showing a positive relationship with the resulting AED. AED received by the skin overlying thyroid gland during a routine mammographic examination under normal clinical settings was found to be within 16.3432µGy–24.5148µGy. Though no significant different was found when compared in respect to the side being imaged in the same projection category (R-CC, L-CC and R-MLO, L-MLO), the radiation dose during MLO was found to be significantly higher than the CC. mAs, kVp, type of the projection, and compressed breast thickness, were identified as the factors affecting AED.

Introduction

Mammography is the x-ray examination of the human breast which is believed as most effective examination for detection of breast cancers in the early stages and it is the most common cancer among women all over the world 2,3,4,5,6. According to the American Cancer Society, the chances of an American female developing breast cancer in her lifetime is about 12%1. Early detection of breast cancer can save many lives every year. However, when compared with other cancer types, breast cancer is detected in the later stages because, in most cases, there are no signs or symptoms of the disease when it progresses 3, 4. Mammograms can be divided into two types: screening and diagnostic mammograms in clinical practice7. Screening mammograms are the x-ray examination of the breasts that are used for scan the breast who have no breast symptoms while diagnostic mammogram used to perform when has suspected benign or malignant breast abnormality.

In Mammography the common practice is to take two views of each breast named as Cranio Caudal (CC) and Medio-Lateral Oblique (MLO) with these additional views also may be required if the information is not found adequately8,10. During
mammography patient could face an increased risk of radiation exposure especially in radiosensitive areas like the thyroid gland and it's susceptible to radiation induced carcinogenesis particularly in childhood and adolescence. Thyroid primarily exposed by scattered x rays which is not useful for imaging purposes. At present, there is limited epidemiological data on thyroid cancer risk associated with low-dose radiation exposures from common diagnostic x-rays. Low dose radiation has been associated with thyroid dysfunction such as thyroid autoimmunity among young females, thyroid cysts in females of all ages and papillary thyroid cancer in younger women. Biological effects from exposure to ionizing radiation will depend upon the total dose received, type of radiation, time interval over which dose received, volume of tissue exposed, part of the body exposed, general state of health, age of the individual, type of cell and the stage of cell division.

Stochastic effect is one of the primary radiation effect it can do mutation to the thyroid glands. The probability of risk increases with the dose. Stochastic effects result due to single or multiple high dose exposure or low level long term exposure. As with any examination that uses ionizing radiation, in mammography there is a stochastic risk of inducing cancer. The probability of stochastic effects occurring increases as the absorbed dose increases. Effects of radiation are cumulative; therefore each dose could cause some risks to a person’s life. Thyroid cancer incidence is increasing throughout the world. According to the American College of Radiology and the Society of Breast Imaging, the dose to the thyroid from mammogram consisting of two views of each breast could range up to 0.005 mGy. The scattered radiation dose received to thyroid during mammography may vary with patient population. Thyroid cancer accounts for approximately 1 -5% of all cancers in females and less than 2% in males. Hence it can be postulated that one reason for increased incidence of thyroid cancer among females compared to males is that most females are being annually exposed to screening mammography and thereby receiving a radiation exposure to the thyroid gland. In order to carefully examine this argument, the radiation dose received to thyroid gland during mammography should be taken into account.

Aim of the study was to assess the accumulated equivalent radiation dose received to the skin overlying thyroid during mammography with respect to the mammography projections of cranio caudal (CC) and medio lateral oblique (MLO) projections or any supplementary projections.

Materials and Methods
Ethical approval for this study was obtained from the ethical review committee of Faculty of Allied Health Sciences, University of Peradeniya. Approval and permission for this study was obtained from particular institution in Kandy, Srilanka. Written informed consent was obtained from the patients at the beginning of the study. The study was designed as an observational descriptive study, was conducted using the mammographic facility in a selected private medical institute, in Srilanka. The study population consisted of a convenience sample of 75 patients. All the patients referred to screening and diagnostic mammograms was included in the study. The mammographic projection, distance between the compression plate to the dosimeter after compression applied, thickness of the compressed breast, mAs, kVp and the film size were measured as variables.

A pre coded data sheet was used to collect data and patient’s demographic data were recorded. The type of the mammography equipment used for the study was Bennette trex and electronic pocket dosimeter (A PDM-117 (MYDOSE mini), weight 50 g) was used to measure the radiation dose to the skin overlying thyroid sensitivity of the dosimeter was 10 to 9999 µSv. It was placed immediately below the palpable thyroid cartilage by the help of specially designed neck collar.

The size of the film used and the distance between the upper border of the compression plate to the detector and location of dosimeter was measured. Exposure factors (kV, mA, and mAs) were recorded. Accumulated equivalent radiation dose to skin overlying the thyroid, resulting from a routine mammographic examination was assessed by averaging the collected dosimeter readings in respect of their projections. Calculated mean values were finally added in accordance with the definition given for the routine mammographic examination which states such an examination should consist of two views of each breast named as CC and MLO. Dosimeter error was also considered and final dose value was recalculated using an error propagation method given below.

\[ \text{AED}_o = \text{AED} \pm \Delta \text{AED} \]

\[ \text{AED}_o - \text{Accumulated Equivalent Dose with error} \]

\[ \text{AED} - \text{Measured Accumulated Equivalent Dose} \]

\[ \Delta \text{AED} - \text{Error of Accumulated Equivalent Dose} \]
RESULTS

Total Sample of 75 patients (all were women) were collected during the period of six (06) months. Mean age of the patients were 51 (±11) years and among 75 patients 80% were referred to diagnostic mammogram while 20% were referred to screening mammogram. Dose values related to CC as had values ranging from 1μGy to 25μGy while the majority was found below 5μGy except in five instances where measurements were recorded higher than 5μGy. In relation to projection CC, R-CC and L-CC received mean values of 3.47μGy and 3.02μGy respectively.

Breast Thickness

In the comparisons made in relation to the distribution of compressed breast thickness (CBT) among both CC and MLO projections the mean value of CBT was higher in MLO (5.32cm) than in the CC (4.76cm). The spread related to CC ranged from 3cm to 6.9cm while in MLO it differs from 3cm to 7.5cm.

Distance

The variable which was measured as the vertical distance from the superior surface of breast compression plate to the dosimeter showed a distribution with mean values of 11.8cm in CC while 10.86cm in MLO respectively.
Graph 4: Distribution of AED Values (µGy) accordance with breast thickness in MLO projection.

Graph 5: Distribution of distance in CC projection.

Graph 6: Distribution of distance in MLO projection.

Graph 7: Distribution tube current (mAs) in CC projection.

Graph 8: Distribution tube current (mAs) in MLO projection.

**Tube Current**

In relation to CC projection, though the recorded mAs values showed a distribution ranging from 80 to 300 mAs most frequently recorded value was 100mAs. It was also found that in relation to the projection of MLO the distribution was from 80mAs to 400mAs. In the subsequent analysis using recorded mAs values the mean values of MLO and CC 210.26 and 148.46 respectively.

**Tube Voltage**

The spread relate to kVp in both the CC and MLO in the range of 25 to 28 and in subsequent analysis it was found that mean value related to MLO (25.75) was higher compared to the mean value of CC. Accumulated Equivalent Radiation Dose received by the skin overlying the Thyroid in a CC projection was found to be within 2.6452μGy to 3.8446μGy.

<table>
<thead>
<tr>
<th>Projection</th>
<th>Mean (µGy)</th>
<th>Range (µGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L- CC</td>
<td>3.02</td>
<td>2.41- 3.63</td>
</tr>
<tr>
<td>R- CC</td>
<td>3.46</td>
<td>2.88 – 4.05</td>
</tr>
<tr>
<td>Average</td>
<td>3.24</td>
<td>2.64 – 3.84</td>
</tr>
</tbody>
</table>

Figure 2: Distribution of cumulated equivalent radiation dose to thyroid in CC projection.

Accumulated Equivalent Radiation Dose received by the skin overlying the Thyroid in a CC projection was found to be within the range of 2.6452µGy to 3.8446µGy.
The average radiation dose received by the skin overlying Thyroid was estimated to be within the range of 5.7468µGy to 8.1924µGy in the projection of MLO.

**Comparison of AEDs among four categories of Projections**

In the comparison made using the hypothesis test Kruskal Wallis, in determining whether the distribution of AEDs measured in each mammographic projections were similar or not, found that distribution of AED values respect to four projections(LCC, RCC, LMLO and RMLO) were not similar (p value was 0.000 < 0.05).

**Comparison of AEDs of R-CC and L-CC**

Mann Whitney U Test was used to compare the resulted AED values of RCC and LCC. Since the resulted p value (0.068) was greater than 0.05 distribution of AED in both the projections was identified similar in respect to their median and mode. Thus AEDs resulted from LCC and RCC were considered as showing no significant difference at a confidence interval of 95%.

**Comparison of AEDs of R-MLO and L-MLO**

As shown in the figure 3, according to the results of the Mann Whitney U Test (p value 0.065> 0.05) AEDs relate to RMLO and LMLO showed no significant difference in their respected distributions of AEDs.

**Comparison of AEDs of CC and MLO**

Mann Whitney U Test was used and As shown in the figure 5.14 since the resulted p value 0.000 was less than 0.05, the distribution of AEDs in MLO and CC projections were considered significantly different with relevant to their median and mode.

**Regression Model**

Log (dose) = {-5.282058 + 0.007203*mAs + 0.189271*kVp +0.360366* Projection (LMLO) + 0.174482* Projection (RCC) + 0.130402* Projection (RMLO) + 0.012511*Breast Thickness}.

R² = 0.6256 and Adjusted R² = 0.6137, so, in either case, about 62.5% of the total variance is explained by the four variables used.
It was also found that the distance from the compression plate to dosimeter was not making a significant effect in explaining the variance of AED.

**DISCUSSION**

This study was carried out to assess the radiation dose to skin overlying thyroid gland during a routine mammographic examination by estimating the resulting accumulated equivalent radiation dose to the skin overlying thyroid gland in 75 female patients at a private hospital, Srilanka. The results showed that measurable amounts (up to 24μGy) of scatter radiation were incident upon the skin overlying the thyroid. Origin of this scatter was believed to be from the compression plate and the breast. Leakage radiation from tube could have also influenced. However a large spread in the measured skin doses was evidenced and this was explained only by partly from the variables measured. Other than the variables measured, target/filtration combinations used in the equipment, subjective preference of the radiographer, sensitivity and accuracy of used automatic exposure control system could have also resulted for the variance in partial.

AEDs’ received by the skin overlying thyroid corresponding to the projections of R-CC and L-CC were found to have no significant differences between them and measured variables related to these have also showed distributions very similar to each other. Right and Left MLO related dose values also showed no significant difference among them. However, surprisingly AEDs’ related to CC and MLO have showed a larger variance and was identified as significantly different at a \( P=0.005 \). The most plausible factor behind this significant difference can be considered as the mAs value, since the average mAs value for MLO projection (219.26) was found to be notably higher compared to CC projection (148.48). Thickness of the compressed breast was also found to be 10.86cm in MLO and 11.80cm in CC creating only a small distance difference of 0.94cm. This may be the cause for the different explanation in relation to the dose difference in MLO and CC in the current study. During this study it was also found that the AED resulted from MLO (6.9696μGy) was on average 2.14 fold higher than the AED resulted from CC (3.2449μGy). In another similar study carried out by Sidney University revealed that the thyroid skin dose from the MLO is on average 1.7 to 3.0 fold higher than the dose from CC\(^{37}\).

In the current study, the average distance from the compression plate to the dosimeter was 11.8cm and 10.86cm for the CC and MLO respectively and when compared was found lower than that of the study results conducted by American school of medical radiation technology in Sydney in Australia. The inherent genetical differences of two study groups and differences in height, size of the breast may have affected in creating this incomparability. However the distance in CC being higher than MLO was comparable in both studies. Total distribution observed among the resulted AED values was identified as having a statistically presentable correlation with several measured variables.

In order to find this correlation a standard linear regression model was used. There it was found that a percentage of 62.5 of the variance (from 1μGy to 25μGy) shown in the AED values were caused by the factors measured as variables during the study. Further these were identified as mAs, compressed breast thickness, kVp, and projection type. In relation to CC projection increase in mAs, kVp, breast thickness all have resulted higher AEDs’. And in relation to MLO projection increase in mAs, kVp, breast thickness also have resulted higher AED’s \(^{34}\). In relation to both the projections kVp related graphs have shown a higher AEDs’ with increasing kVp. Though it is not justifiable when considered high kVp values (40kV and above), in mammography as we are using a very low kVp range (24 – 28 was used in the current study) it can be thought that the resulted increase of AEDs’ could have resulted due to the fact that, when the energy of the incident photon is increased resulting scatter photon energies are also increasing there by allowing them to travel more distance and giving a more chance in get detected by the dosimeter. Thus according to the findings we made in practice it would be more justifiable if appropriate low kVp values could be used with the aim of purely reducing the radiation dose to the thyroid. According to the findings made by Mohammad Zeidan, University of Canterbury, compressed breast thickness is considered very important in mammography as inadequate compression would cause radiation penetrating...
length to be increased and thus resulting a higher amount of scatter radiation. Further confirming this fact during the present study it was also found that compressed breast thickness had contributed to the resulted AEDs and where the breast thickness was high the resulted AED was also recorded as high. Therefore it can be argued that by applying an adequate level of compression radiation dose to the thyroid gland can be minimized. CC and MLO projections involve equipment to be prepared in two different angulations in respect to the vertical. It makes the scatter passing distance to be varied in relation to the amount of soft tissue and bony areas found in the way to the thyroids. This may also have partially affected the dose in MLO to be higher than the dose in CC. While the measurement of skin dose at the thyroid may, in some instances, serve as a conservative estimate of thyroid dose it is not valid for low-beam energies, particularly those used in mammography.

After considering the depth dose data from the literature, it was decided to use a 10% of the skin dose as the actual thyroid dose. Following application of this theory the actual thyroid radiation dose was found to be within the range of 1.63 μGy – 2.45 μGy. The following table shows a comparison of radiation dose levels to thyroid of present study levels with similar studies carried out previously.

CONCLUSION

AED received by the skin overlying thyroid gland during a routine mammographic examination carried out using Bennet trex mammography system under normal clinical settings was found to be within the range of 16.3432 μGy – 24.5148 μGy. Though no significant difference was found when compared, in respect to the side being imaged in the same projection category (R-CC, L-CC and R-MLO, L-MLO), dose in MLO was found to be significantly higher than the CC. Recorded mAs, kVp, and measured breast thickness each showed a positive relationship with the resulting AED. mAs, kVp, type of the projection, and compressed breast thickness, were identified as the factors affecting AED.

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