고신대학교 의과대학 학술지 제21권 제1호
Kosin Medical Journal
Vol. 21. No. 1, pp. 256~259, 2006

폐암에서 흉부부위 방사선 조사 시 갑상선의 방사선량

김수길

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Thyroid Dose During Thoracic Irradiation in Lung Cancer

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Abstract

Background: To determine the radiation dose received to the thyroid gland as a result of thoracic irradiation in the patients with lung cancers, and the factors influencing that dose.
Methods: The dose to the thyroid resulting from the simulated irradiation of the chest of an adult anthropomorphic(humanoid) phantom with 6MV X-rays was measured using thermoluminescent dosimeters (TLDs). The dependence of dose on the distance of the x-ray source was measured. The effects of a bolus was also determined.
Results: Using shielded field, the thyroid region received 13-16% of the prescribed dose on the surface of phantom and 32-33% in phantom for 6MV X-rays. The dose increased as the measurement point on skin closer to the x-ray source due to tissue scatter. Placement of a bolus around the neck increase the thyroid dose by 30% compared to the thyroid dose without bolus.
Conclusion: For prophylactic irradiation doses of 2000 cGy in the adult phantom, the dose to the thyroid was about 300 cGy(15%). As the thyroid is very sensitive to radiation and the dose-response curve for thyroid tumor induction is linear, attempts to shield the thyroid during prophylactic irradiation are mandatory. The use of shielding block and bolus were important factors in determining thyroid dose.

Key words : prophylactic irradiation, TLD, humanoid phantom, thyroid dose, bolus

Introduction

Radiation-induced thyroid cancer is a well-described phenomenon associated with thoracic irradiation of both benign and malignant condition in the thoracic region.[1] Mechanisms of tumor induction include radiation dose to the thyroid,[2] and radiation-induced damage to the pituitary gland exacerbating thyroid tumorogenesis.[3]

Although there have been many publications regarding the dose outside the treatment field, I considered that they do not address my situation directly; therefore I measured the dose from prophylactic irradiation to the thyroid region of a phantom and the physical factors contributing to that dose

Methods and materials

1. Phantom irradiations

An adult anthropomorphic phantom (Alderson Research Laboratories Inc. Stanford, CT) was irradiated using 6MV X-rays (Varian Clinac 1800 linear accelerator) at 101.5 cm FSD(focus-skin distance) at 100cm SSD(source-skin distance). The humanoid phantom mimics the soft tissue

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and bone structure of an adult human for tissue substitutes in radiation dosimetry(Fig.1).

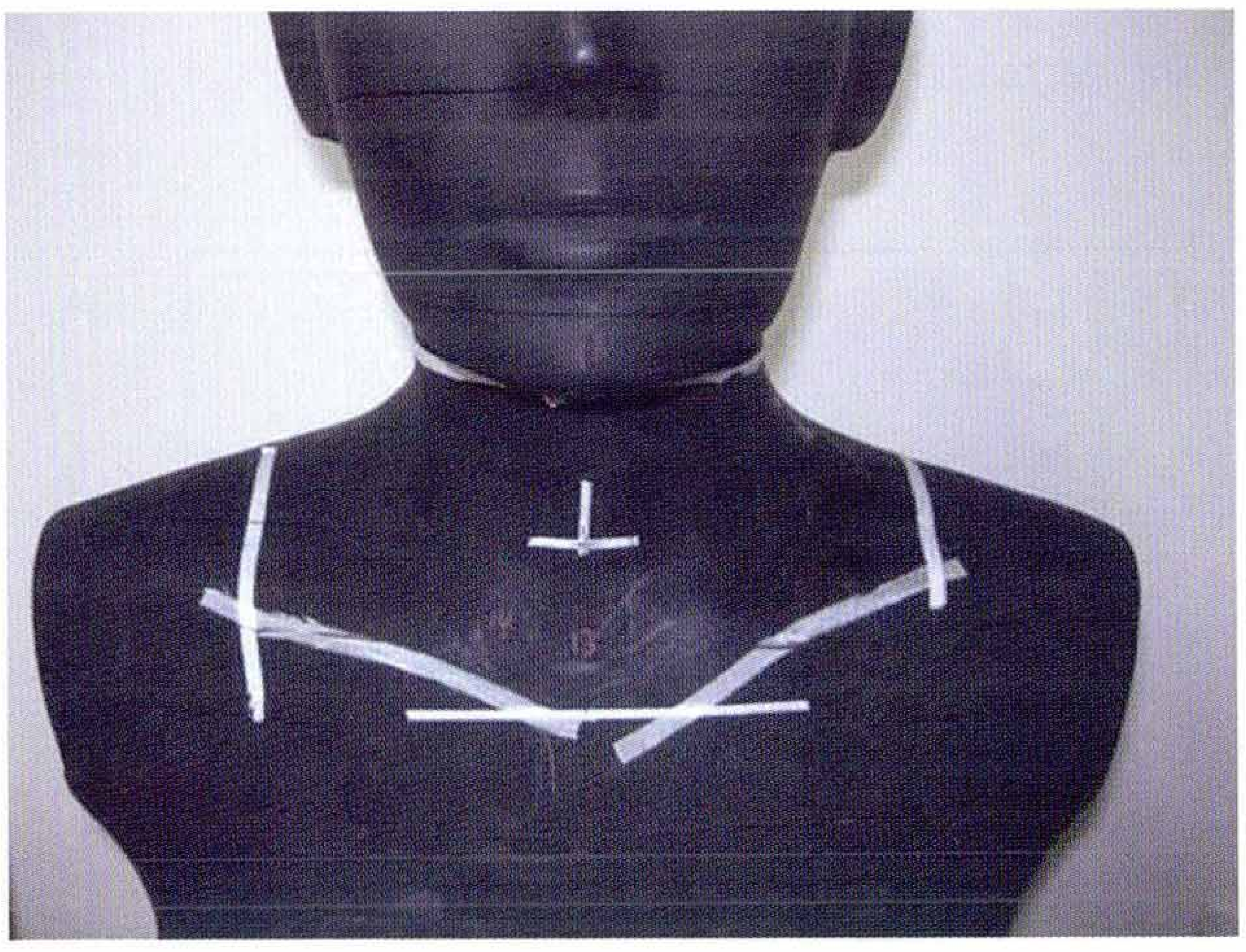

Fig. 1 Anthropomorphic phantom irradiation setup without bolus. rectangular fields 19.5cm x 9cm were used. The central axis of each field passed through slice No. 10 of the phantom and the inferior field edge passed through the No. 9 and the No. 12 .

For initial measurements, rectangular fields 19.5cm x 9cm were used. The central axis of each field passed through slice No. 10 (Fig.2) of the phantom and the inferior field edge passed through the No. 9 and the No. 12 . Doses of 100 cGy to the midline were delivered for all phantom experiments, based on treatment plans.

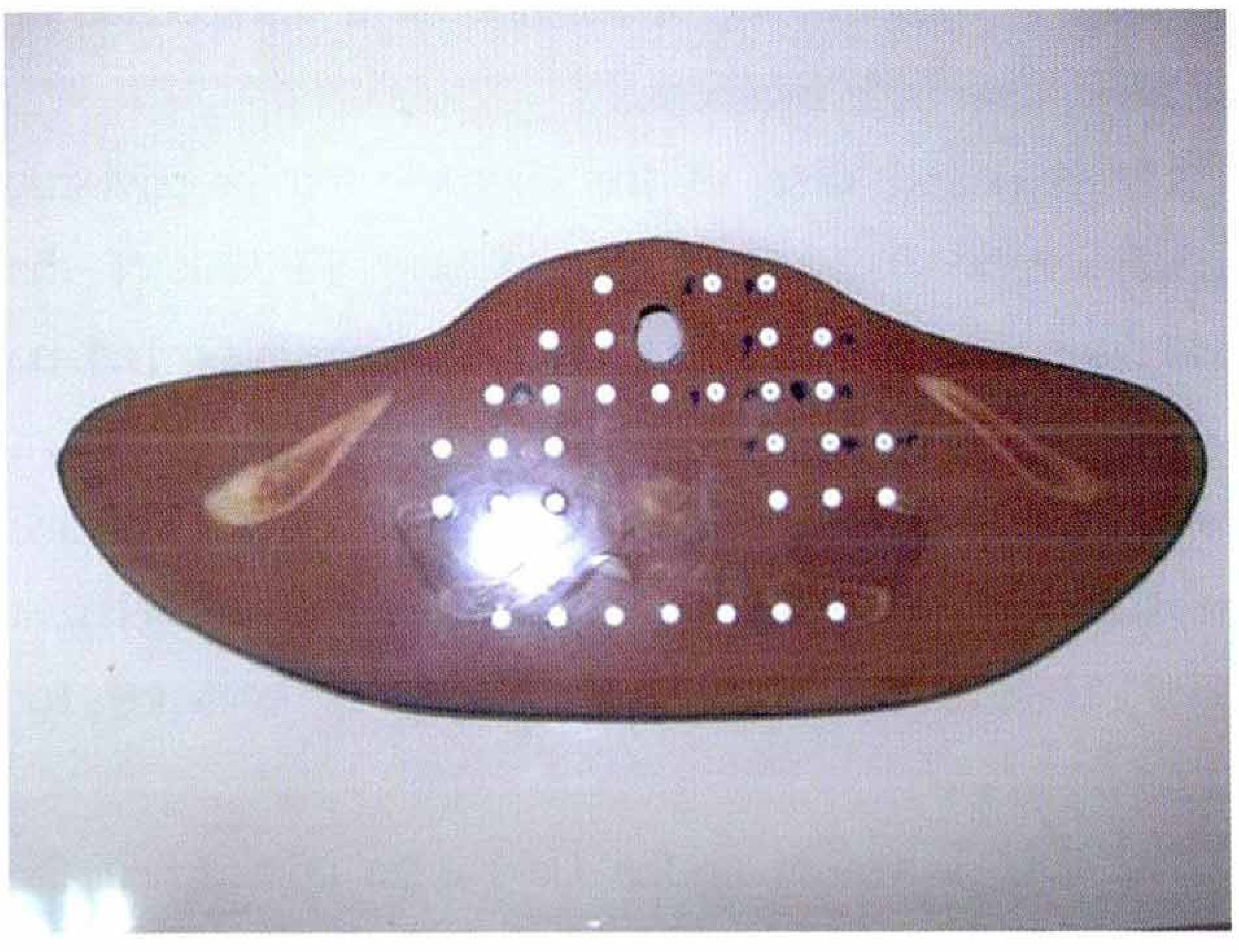

Fig. 2 Slice No. 9 of phantom. TLD position 6, 8 are deep thyroid region.

2. Dose measurement

A new batch of 50 lithium fluoride rods(Harshaw TLD-100; dimensions 1mm diameter, 6mm long) were used as thermoluminescent dosimeters(TLD). TLD output were readout in a automated TLD reader (Harshaw/Bicron, TLD reader 5500) in a two step read-out cycle. All dosimeters were annealed in a dedicated annealing oven. TLD calibration was performed with the standard calibration geometry of a 10cm x 10cm field at 100cm SSD with TLDs placed at the central axis at the depth of maximum dose using appropriate thicknesses of solid water. Each TLD was calibrated individually with a dose of 100cGy. Calibration was performed before and after each set of measurements and the calibration factor was calculated for each TLD from the average of these measurements to account for changes in TLD sensitivity between exposures. The uncertainty in TLD readings was 3%(one standard deviation) based on a series of repeated exposures.

The position of the thyroid gland in the neck was assumed to lie in slice No. 9 of the humanoid Phantom(Fig.1). 5 TLDs were placed in the region of the thyroid. 2 were inserted within slice No. 10 of the phantom, as TLDs 0.7-2cm below the anterior surface (positions 6, 7), as shown in Fig. 2. The remaining 3 TLDs were placed on the surface of the neck of the phantom so that the TLDs were positioned across the thyroid(positions 2-4).

3. Thyroid dose

The total dose to the thyroid was assumed to be the sum of two components, namely external stray radiation and tissue scattered radiation. Stray radiation comprised leakage and scattered radiation of the primary beam from various gantry components (jaws, shielding trays, etc.). Tissue scatter was radiation scattered from the patient (or phantom).

To simulate routine treatment methods more closely, measurements of thyroid dose were repeated with a shadow tray supporting lead blocks. These were a 7-cm-thick lead block which was aligned along the inferior border of the field to shield the body from stray radiation, and a small block to provide additional shielding of the thyroid.

No bolus of the thyroid was undertaken. Bolus is 1.5-cm-thick tissue equivalent material covered on the skin to increase the absorbed dose on skin. The prescribed daily dose was 100 cGy to the midline of the central axis. During the irradiation, the TLDs were placed across the anterior neck of the patient at the level of the mid-thyroid. Humanoid phantom received 2000cGy midplane neck dose with 6MV X-rays at 100 cm SSD. Thyroid dose measurement with bolus also was undertaken. comparison between the thyroid dose measurements with bolus and without bolus was made.

Results

For the standard setup on the humanoid phantom, Table 1 lists the percentage doses received by the thyroid as a function of TLD position following 100 cGy of 6 MV. Using sheilded field, the TLDs at deep thyroid region received 32-33% of the midplane dose and the TLDs at superficial region received 13-16%. The effect on the thyroid dose of bolus with attached lead shielding is indicated in Table 1 for 6MV. The presence of a bolus alone increased the dose at deep and superficial positions by 21% and 200%, respectively, relative to measurements without bolus.

Table.1 Phantom dose measurements for 6MV (Percentage of midline dose) of deep TLDs 0.7-2cm below the anterior surface(positions 6, 7), and superficial TLDs placed on the surface of the neck of the phantom (positions 2-4) so that the TLDs were positioned across the thyroid as shown in Fig. 2.

TLD position	6 (deep)	8 (deep)	2 (superficial)	3 (superficial)	4 (superficial)
dose (%)	33	32	15	13	16
with bolus (%)	36	39	33	28	35

The dose increased as the measurement point on skin closer to the x-ray source due to tissue scatter. As the distance from the inferior field edge to the measurement point decreased, the dose increased steadily(Fig.4).

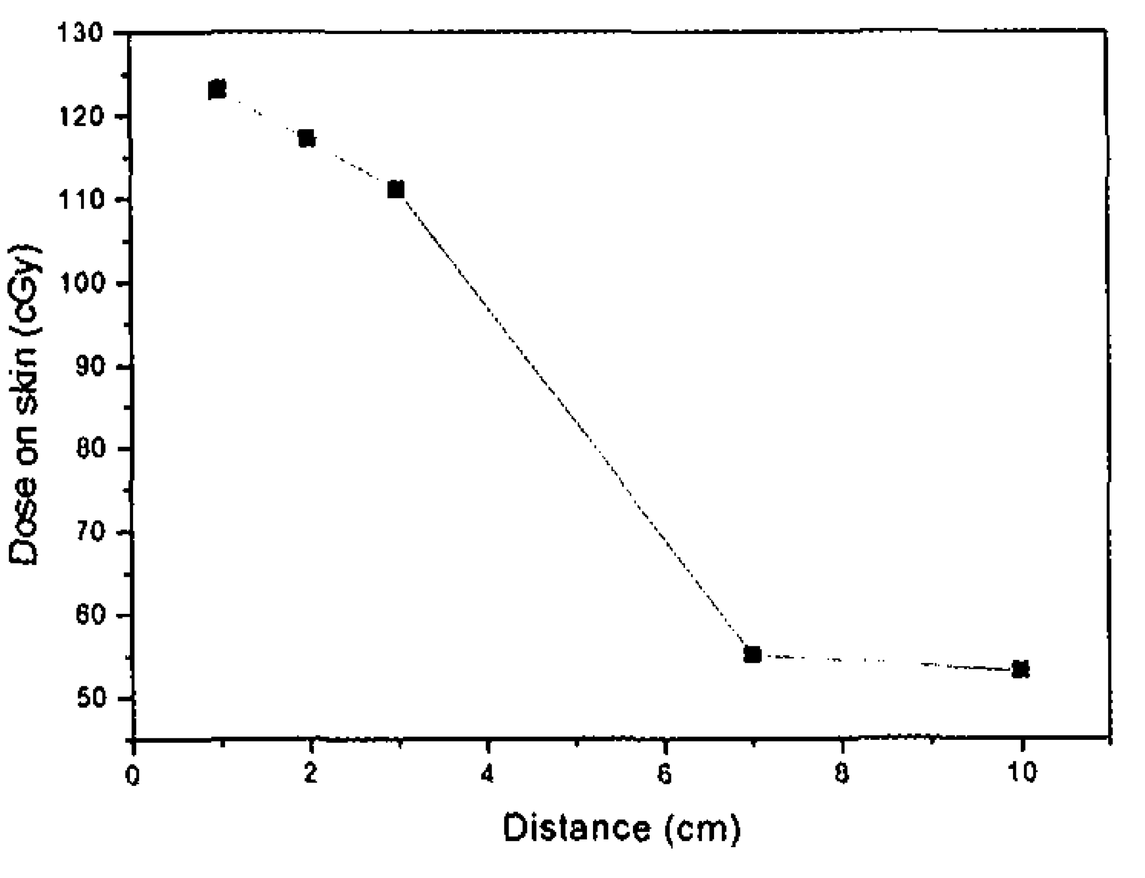

Fig. 4 Relationship between dose (as cGy of midline dose) and distance of measurement point from field edge.

Discussion

Thoracic irradiation remains a component of many treatment sheedules for lung cancer because it significantly reduces the incidence of subsequent lymphatic cancer. Although radiation-induced thyroid malignancy may be a "vanishing problem" as a result of cessation of irradiation for benign disease, the subject will be remained of concern as long as prophylactic irradiation is a component of curative treatment regimens.

My measured dose to the thyroid, for prophylactic irradiation to the adult phantom, was 13-33% of the midplane thyroid dose for 6MV. As the TLDs had no overlying buildup material, this suggests that a significant proportion of the stray radiation outside the field was due to electrons.[4] Similarly, the large increases in superficial dose when a blous used provide good evidence for build-up effect.

The dose increased as the field edge approached the measurement point (Fig. 4). According to G. Stevens,[5] at least half of the dose to the thyroid could be eliminated by shielding the thyroid from stray radiation. In practice, however, placement of shieding blocks on the shadow tray to reduce thyroid dose was much less effective. In fact, the use of a shadow tray and thyroid block reduced the thyroid dose by only 20% compared with arrangement without bolus.

Shielding of stray radiation would be much more effective when a shielding block was placed adjacent to the thyroid, compared with a block place in the shadow tray, which itself generates additional scatter; however, there are practical difficulties in supporting a heavy lead block adjacent to the face and neck.

Fig. 3 Anthropomorphic phantom irradiation setup with bolus

Conclusion

A general principle in radiation therapy is dose minimization outside the target volume. We have demonstrated that the thyroid can receive up to 39% of the prescribed prophylactic irradiation dose using the bolus around neck as shown Fig.3 for 6MV X-rays at 100cm SSD. This dose could be reduced by on half to two thirds by minimizing stray radiation through placement of a shielding block adjacent to the thyroid. The use of lead shielding blocks supported on a shadow tray was much less effective. Due to the linear dose response relationship for induction of thyroid cancer at doses exceeding 10cGy, attention to these will result in a significant reduction in the risk of thyroid cancer.

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