*Bangladesh Journal of Physics, Vol. **32**, Issue 1, pp. 13 – 19, June 2025*

ASSESSMENT OF PERIPHERAL PHOTON BEAM SKIN DOSE USING MTS-7 TL CRYSTAL FOR 15 MV ELEKTA MEDICAL LINAC

M. U. H. MUSFIKA[1,2], A. K. M. MOINUL HAQUE MEAZE[1,3*], H. M. JAMIL[4], K. M. M. MORSHED[4], MD SHAKILUR RAHMAN[4], NOURIN AROBI[5], SANTUNU PUROHIT[1]

[1]Department of Physics, University of Chittagong, Chattogram-4331, Bangladesh
[2]International University of Business Agriculture and Technology (IUBAT), Uttara Model Town, Dhaka-1230, Bangladesh
[3]Faculty of Natural Sciences, Asian University for Women, Chittagong, Bangladesh
[4]Secondary Standard Dosimetry Laboratory, Bangladesh Atomic Energy Commission, Savar, Dhaka-1349, Bangladesh
[5]Jahangirnagar University, Savar, Dhaka-1342, Bangladesh

**Corresponding author email: meaze@cu.ac.bd, moinul.haque@auw.edu.bd*
Received on 25.12.2024, Revised received on 15.06.2025, Accepted for publication on 16.06.2025

DOI: ***https://doi.org/10.3329/bjphy.v32i1.83754***

ABSTRACT

High energy linear accelerators are being used for treatment of cancer patients. In radiotherapy, the peripheral doses also attack the normal and healthy cells. According to the suggestion of LNT model, the issue of peripheral dose cannot be neglected. This study investigated the outfield photon beam skin dose in radiotherapy of Elekta medical Linac operated at 15 MV operational voltage using MTS-7 TL crystal. Before Linac exposure, TLDs were calibrated using ^{137}Cs source. Then, TLDs were inserted on the phantom surface for Linac exposure. This study found that the photon skin dose increases with the increase of delivered dose and field size. As a function of the delivered dose, the highest doses were found 181.65 mSv and 78.39 mSv for delivered dose 300 cGy with field size 10×10 cm^2 for Linac-1 and Linac-2 respectively. While, investigating the field dependency, the highest dose was found 511.30 mSv for field size 20×20 cm^2 for 200 cGy delivered dose (Linac-1). According to the LNT model, this undesired radiation exposure may arise the risk of second cancer which makes this study extremely mandatory.

Keywords: *Cancer, Radiotherapy, Second cancer, TLD, MTS-7, Linac, Photon dose, LNT model*

1. INTRODUCTION

Over fifty percent of cancer cases involve radiotherapy, and 40% of cancer patients have been cured undergoing radiotherapy as part of their treatment. The most popular kind of radiation therapy is external beam, which typically uses high-energy photons that can be targeted to treat a particular part of the body [1]. Medical Linear accelerators (Linacs) are increasingly used in medical field [2]. Currently, Medical Linac can create photon beams with energies ranging from 4 to 25 MV [3]. Radiotherapy can be viewed as a hidden disadvantage because it may increase the risk of developing a second cancer, even though it is a blessing for cancer patients worldwide, including in Bangladesh. Recently, the radiation induced risk of second cancer have become a major issue of concern [4,5]. Very high doses are required to be delivered

depending on the type and stage of the cancer, but with the increase of energy deposited to target, the risk of second cancer increases [5].
The goal of the radiotherapy is deposition of the required amount of dose to the cancerous tissues at the same time protecting the healthy tissues. Treatment planning systems (TPS) are designed in such a way to deliver only the desired doses to the target point of the organ avoiding the surrounding healthy tissues [6]. However, for many reasons, the goal of radiotherapy is not fully achieved. Thus, the delivered doses reach to the adjacent regions of the target organ which are considered as the outfield dose also known as peripheral dose [7]. Thus, the study of outfield dose in a radiotherapy treatment is more than necessary to ensure a quality treatment. Though the peripheral dose is not always very significant in amount compared to the delivered dose, the risk issue cannot be ignored according to the linear no-threshold (LNT) model. This model suggests that there is no threshold level of radiation exposure below which the risk is negligible. According to the LNT model, the risk is directly proportional to the radiation exposure [8]. This study involves measuring the peripheral photon beam skin dose in radiotherapy for 15 MV medical Linac using MTS-7 crystal of Thermoluminescent Dosimeter, as ^{7}LiF:Mg,Ti (MTS) crystal shows sensitivity to photon radiation across different energy level [9].
Rajesh et al. measured peripheral dose with diode and thermoluminescence dosimeter for intensity modulated radiotherapy (IMRT) with linear accelerator (conventional LINAC), and tomotherapy (novel LINAC), compared with each other. They indicated leakage as primary contributor and scattered radiation as the secondary contributor [10].
Vassiliki Vlachopoulou et al. measured peripheral dose in high-energy photon radiotherapy with the implementation of MOSFET and observed that the percentage of peripheral dose decreases almost exponentially with the increase of distance from the field edge [11].

2. MATERIALS AND METHODS

The study can be broadly categorized into two main phases: calibration process and the experimental process.

Fig. 1: TL crystals inside card holder.

2.1 Calibration of TLD

TLDs (Fig.1) of Radpro manufacturer were employed for measuring outfield photon beam skin dose. Albedo TLD contains four crystals; two crystals of MTS-6 which are enriched in ^{6}Li sensitive to neutrons and MTS-7 having a negligible neutron sensitivity but sensitive to photon. Before irradiating the TLDs to Linac dose, TLDs were calibrated in Secondary Standard Dosimetry Laboratory under ^{137}Cs source using Gamma calibrator G10, with a tissue equivalent slab phantom selected for its symmetry, as shown in Fig. 2. For calculation of irradiation time of ^{137}Cs source, the dosimetry of the source in air was carried out. To observe the calibration data and experimental data, TLDs were read by RE 2000 TL reader. Before Linac irradiation, zero doses of TLDs were read and recorded using Thermosoft WinTLD software.

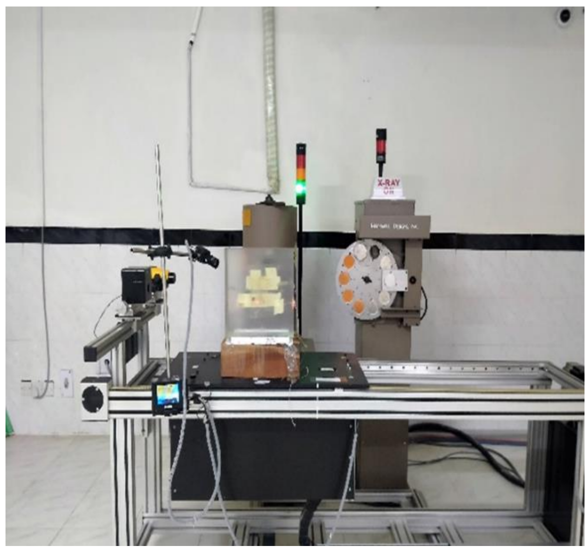

Fig. 2:^{137}Cs irradiation for the calibration of TLDs by G-10.

2.2 Linac exposure on Alderson Rando Phantom

Two Elekta synergy medical Linacs of Enam Medical College and Hospital were used in this investigation process. The calibrated TLDs were placed inside Alnor TLD badge and placed on the surface of Alderson Rando Male Phantom on different organs, as the Fig. 3 shows. Then, the Phantom was irradiated under Linac exposure for different dose deliveries and field size(s), as shown in Fig. 4. The beam was targeted to the lung centre of the Phantom body surface. The term 'Lung Center' is used to describe the space between the left and right lungs (anatomically known as the mediastinum region). The central badge was positioned at 0 cm. Lung region badges were placed 2.5 cm laterally to the right and left of the center. Another badge was positioned at 15 cm (toward the feet) for the upper abdomen region, relative to the target. This study involves measuring the photon skin dose outside the target region. To understand the dose dependency, 100 cGy, 200 cGy and 300 cGy were delivered keeping the SSD at 100 cm for field size 10 × 10 cm^{2}. To know the field dependency, the dose delivery was kept fixed at 200 cGy at 100 cm SSD with varying field sizes.

Fig. 3: TLD set up on Alderson Rando phantom placed on the Linac treatment couch.

Fig. 4: Camera view during irradiating TLDs in 15 MV Linac (Elekta type) in Enam Medical College & Hospital, Savar, Bangladesh.

3. RESULT AND DISCUSSION

3.1 TLD Calibration

The calibration factors are not similar for all crystals but the values are very close to 1, because it may vary crystal to crystal depending on the way they have been produced and the age of their use. To guarantee accuracy, the dose estimations were performed using the unique calibration factor for each TLD. The gamma calibration factors of the TLDs are shown in the Fig. 5.

3.2 Outfield Photon dose as a function of the delivered dose

For the both Linacs, the highest dose is observed for 300 cGy dose delivery. As the radiation beam was delivered to the direction of the Lung Center of the Phantom i.e.; located at 0 cm , the Left Lung and the Right Lung were closer (at 2.5 cm) to the Lung Centre compared to the upper abdomen (at 15 cm). The dose values in the Right Lung &Left Lung are greater compared to upper abdomen, which means scattered photon dose decreases with the increase of distance from the field region. Also Fig. 6 & Fig. 7 indicate that photon skin dose increases with the increase of delivered dose.

3.3 Outfield Photon dose as a function of field size

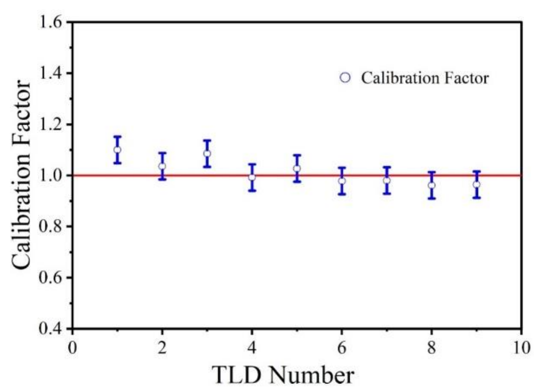

Fig. 5: Gamma calibration factor of MTS-7 for crystal position-2 of Albedo TLD.

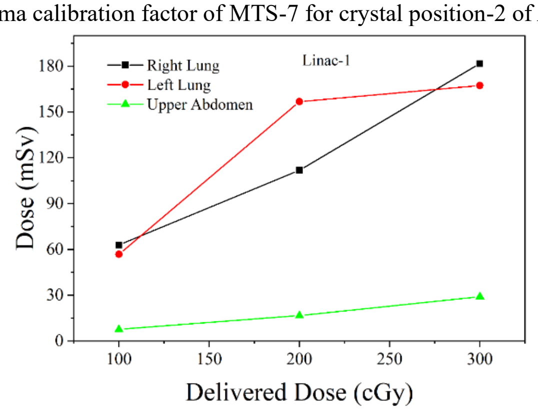

Fig. 6: Photon skin dose response as a function of the delivered dose for Linac-1.

For all field sizes, the beam position was consistently directed towards the Lung Center, ensuring that the lungs were outside of the direct exposure of the photon beam but close to its edge. Fig. 8 shows that the photon dose increases with the increase of field size. This is because, with the increase of field size, the radiation beam gets wider path to pass outside. *Vassiliki et al.* observed that because of the increased scattering volume, the percentage of peripheral dosage is much higher for bigger field sizes for a given distance [11]. *Attalla et al.* also presented that skin dose increased with increase of field size [12]. Field size 20 × 20 cm^2 generated the highest dose, accounting for 25.5% of the delivered dose. The TLDs were placed on an Alderson Rando phantom, with the target region being the middle area between the Lungs. Since the Lungs were on the field edge, this resulted in the high peripheral dose.

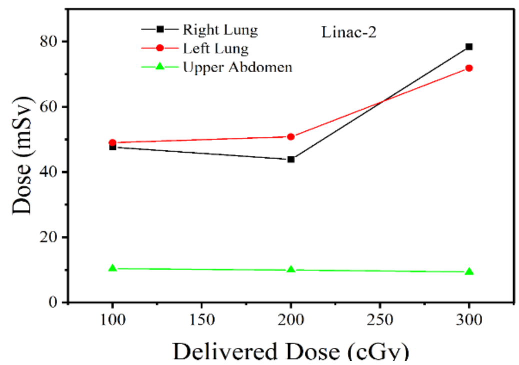

Fig. 7: Photon skin dose response as a function of the delivered dose for Linac-2.

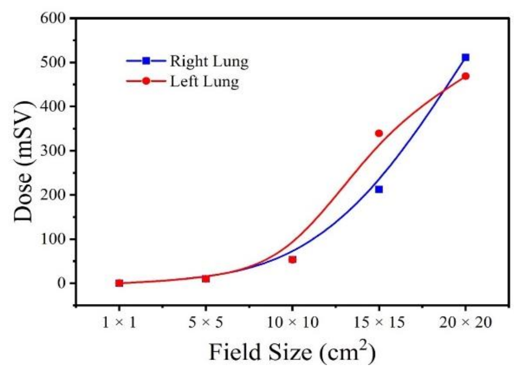

Fig. 8: Photon skin dose response as a function of the field size(s) for Linac-2.

4. CONCLUSIONS

Peripheral photon skin dose was measured as a function of delivered dose and field size for 15 MV Elekta medical Linac using MTS-7 crystal of TLD. While observing the peripheral dose as function of delivered dose, the highest doses were found for 300 cGy at 10 × 10 cm^2which were 6.04% and 2.6 % of the delivered dose for Linac-1 and Linac-2 respectively. And the highest dose was found for 20 × 20 cm^2 which is 25.5 % of the delivered dose in case of examining field size dependency. This study discovered that the peripheral dose increased with the increase of the delivered dose and field size. This study might raise concerns about using a modified treatment planning system to reduce the peripheral dose.

5. ACKNOWLEDGEMENT

Authors are grateful to the Enam Medical College and Hospital, Savar, Dhaka, Bangladesh for their co-operation and Secondary Standard Dosimetry Laboratory, Bangladesh Atomic Energy Commission, Bangladesh for giving permission to conduct this study.

REFERENCES

[1] Owadally, Waheeda, and John Staffurth. "Principles of cancer treatment by radiotherapy." Surgery (Oxford) 33, no. 3 (2015): 127-130.

[2] Yücel, H., Çobanbaş, İ., Kolbaşı, A., Yüksel, A. Ö., & Kaya, V. (2016). Measurement of photo-neutron dose from an 18-MV medical linac using a foil activation method in view of radiation protection of patients. *Nuclear engineering and technology*, *48*(2), 525-532.

[3] Najafi, M., M. R. Deevband, DIBA AA YOUSEFI, and MOGHADDAM A. AMIN. "Determination of room entry times for radiation therapists after routine 15 MV photon treatments." (2015): 379-382.

[4] Behmadi, M., H. Gholamhosseinian, M. Mohammadi, Sh Naseri, M. Momennezhad, Sh Bayani, and MT BahreyniToossi. "Evaluation of breast cancer radiation therapy techniques in outfield organs of rando phantom with thermoluminescence dosimeter." *Journal of Biomedical Physics & Engineering* 9, no. 2 (2019): 179.

[5] D'Arienzo, Marco, Stefano G. Masciullo, Vitaliana De Sanctis, Mattia F. Osti, Laura Chiacchiararelli, and Riccardo M. Enrici. "Integral dose and radiation-induced secondary malignancies: comparison between stereotactic body radiation therapy and three-dimensional conformal radiotherapy." *International journal of environmental research and public health* 9, no. 11 (2012): 4223-4240.

[6] Khan, Faiz M., and John P. Gibbons. *Khan's the physics of radiation therapy*. Lippincott Williams & Wilkins, 2014.

[7] Kragl, G., Baier, F., Lutz, S., Albrich, D., Dalaryd, M., Kroupa, B., Wiezorek, T., Knöös, T. and Georg, D., 2011. Flattening filter free beams in SBRT and IMRT: dosimetric assessment of peripheral doses. *Zeitschrift für medizinischePhysik*, *21*(2), pp.91-101.

[8] Cullom, S. JAMES, and Timothy M. Bateman. "Radiation considerations for cardiac nuclear and computed tomography imaging." *Clinical Nuclear Cardiology. Elsevier Inc* (2010): 149-162.

[9] Parisi, A., Dabin, J., Schoonjans, W., Van Hoey, O., Mégret, P., &Vanhavere, F. (2019). Photon energy response of LiF: Mg, Ti (MTS) and LiF: Mg, Cu, P (MCP) thermoluminescent detectors: Experimental measurements and microdosimetric modeling. *Radiation Physics and Chemistry*, *163*, 67-73.

[10] Kinhikar, R., Gamre, P., Tambe, C., Kadam, S., Biju, G., Suryaprakash, Magai, C. S., Dhote, D., Shrivastava, S., & Deshpande, D. (2013). Peripheral dose measurements with diode and thermoluminescence dosimeters for intensity modulated radiotherapy delivered with conventional and un-conventional linear accelerator. *Journal of medical physics*, *38*(1), 4–8.

[11] Vlachopoulou, V., Malatara, G., Delis, H., Theodorou, K., Kardamakis, D., & Panayiotakis, G. (2010). Peripheral dose measurement in high-energy photon radiotherapy with the implementation of MOSFET. *World journal of radiology*, *2*(11), 434.

[12] Attalla, E. M., El-Sayed, A. A., Hessein, H., Abouelenein, H. S., & Ashour, E. F. (2017). Surface dose assessment for different clinical set up parameters from high energy photon beams. *Adv Practice Nurs*, *2*(133), 2573-0347.