ANALYZING THE CONSISTENCY OF BEAM QUALITY AND OUTPUT DOSE/MU FOR PHOTON BEAMS OF ENERGY 6 MV AND 15 MV OF A MEDICAL LINAC USED FOR RADIOTHERAPY AT INSTITUTE OF NUCLEAR MEDICAL PHYSICS, AERE, SAVAR.

M.A. Hasnat[1], K.M.M. Morshed[2], M.M. Parvej[1], M.S. Sultana[1], Juwel Hosen[1], M.M. Ahasan[1], S. Akter[3], A.N. Monika[3]

[1]*Institute of Nuclear Medical Physics, BAEC, Bangladesh*
[2]*Department of Health Physics and Radioactive Waste Management Unit, INST, BAEC, Bangladesh*
[3]*Department of Medical Physics, Atomic Energy Centre, BAEC, Bangladesh*

ABSTRACT

Medical Linac (linear accelerator) delivers ionizing radiation which is used for cancer management. In radiotherapy, it is mandatory to provide maximum dose to the cancerous tumor and minimum dose to the surrounding normal tissues. So it is required to assess the consistency of beam quality and beam output dose/MU (Monitor Unit).

The output dose of Linac (Model: CLINAC-iX) of photon beam of energy 6 MV and 15 MV installed at Institute of Nuclear Medical Physics, AERE Savar has been measured with FC65-P ionization chamber using 1D Water Phantom. In this study, data collection period was from October 2019 to September 2022 in accordance with the TRS-398 dosimetry protocols.

Over the period of 36 months we found that $TPR_{20,10}$ for 6 MV photon beam was 0.67 corresponding and $TPR_{20,10}$ for 15 MV photon was 0.76. Which showed that the values of beam quality $TPR_{20,10}$ never changed when the values are rounded to two decimal points. The measured output dose/MU was found in between 0.998 to 1.023 cGy for 6MV photon and 0.998 to 1.032 cGy for 15MV photon. The dose/MU for all radiation beams was maintained within 2% of deviation from the recommended value 1cGy/MU at D_{max} position over the period of 36 months. In our study, the observed deviations of output dose/MU were maintained in tolerance interval instructed by the protocol. If the tolerance crossed the machine tuned of the monitor unit for getting 1 cGy/MU at the D_{max} position in water. Here, absorbed dose to water based protocol was followed which reduced the uncertainty of the accuracy of the dose determination.

Keyword - *Dosimetry, Consistency, Beam Quality, Output Dose*

---

1. INTRODUCTION:

Cancer is one of the most leading causes of death worldwide, accounting for nearly 10 million deaths in 2020, or nearly one in six deaths.[1] Cancer is caused when cells divide uncontrollably and spread out to adjacent tissues.

Cancer can start almost anywhere in the human body and cancerous tumors (also known as malignant tumors) spread into or invade nearby tissues and can travel to distant places in the body to form new tumors (distant metastasis). Among various types of cancer management systems, Radiotherapy is one of the most common and effective parts of cancer management, where it is mandatory to provide maximum dose to the targeted cancerous tumor and minimum dose to the surrounding healthy tissues.[2] In radiotherapy a high dose of radiation is used to control cancer by killing cancer cells and shrinking the tumors. In radiation therapy ionizing radiation is generally delivered as a part of cancer management that is usually provided by a linear accelerator. Linac is a sophisticated device to produce radiation which is commonly used for radiotherapy in clinical application. The success of external beam radiotherapy is mainly dependent on how the quality control, quality assurance and other precautions are maintained before the beam is heated to infected cells.[3]

Quality Assurance defined as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given requirements for quality. In radiotherapy Quality Assurance contains all procedures that ensure consistency of the medical prescription, and safe fulfillment of that radiotherapy related prescription. Quality Control is the regulatory process to measure actual quality performance for comparison with the existing standards, and the actions necessary to keep or regain conformance with the standards.[4] QC & QA play a significant role for the maximum dose to the cancerous tumor (to the target volume), minimal dose to normal tissue, adequate patient monitoring aimed at determining the optimum end result of the treatment (ultimate benefit to the patient) and minimal exposure of personnel. Therefore, it is important to analyze the consistency of output dose/MU and beam quality of linear accelerators used for radiotherapy.[5]

The purpose of this study is to analyze the consistency of output dose/MU and beam quality for photon beam of energy 6 MV and 15 MV using a medical LINAC machine (Varian iX-SN6298) used for radiotherapy at Institute of Nuclear Medical Physics, AERE, Savar.

2. MATERIALS AND METHODS

The measurements were conducted using a medical linear accelerator; a one dimensional water phantom complied with IAEA TRS-398 dosimetry protocols; an FC-65p type waterproof cylindrical ionization chamber and an electrometer. The specifications of the materials are given in table 1.

Table -1: The specifications of the materials for the determination of photon beam quality and output dose/MU

Material or Machine Name	Specifications and Descriptions
Medical Linear Accelerator	Manufacture: Varian , America
	Model: CLINAC-iX
	Serial No. 6298
	Location: Institute of Nuclear Medical Physics, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh
	Photon energies: 6 MV & 15 MV
	Electron energies: 6 MeV, 9 MeV, 12 MeV, 15 MeV & 18 MeV
1D Water Phantom	Manufacture: IBA dosimetry system, Germany
	Wall material: PMMA
	Tank size: 40 cm (L) x 34 cm (W) x 35 cm (H) (inner dimensions) 42 cm (L) x 36 cm (W) x 36 cm (H) (exterior dimensions)
	Volume ≈ 45 litres
	Chamber support: carbon fibre reinforced plastic
	Max. vertical scan range: 25 cm
	Position resolution: 0.1 mm
	Position accuracy: ± 0.2 mm
	Position reproducibility: ± 0.1 mm
Electrometer (Dose 1)	Manufacture: IBA dosimetry system, Germany
	Channel: single

	Connector type: TNC triaxial threaded
	Maximum Polarization voltage: ± 600V
	Bias Voltage Control: programmable in steps of 1V
Ion-chamber (FC-65p)	Manufacture: IBA dosimetry system, Germany
	Type: water proof, Cylindrical
	Cavity volume: 0.65cm^3
	Cavity length: 23.1mm
	Cavity radius: 3.1mm
	Wall material: POM1
	Wall thickness: 0.057(g/cm2)
	Central electrode material: Aluminium

2.1 DETERMINATION OF THE BEAM QUALITY $TPR_{20,10}$

$TPR_{20,10}$ is the tissue-phantom ratio in water at depths of 20 g/cm^2 and 10 g/cm^2, for a field size of 10 cm x 10 cm and a SCD (source to chamber distance) is kept fixed at 100 cm, which is used for the beam quality index for high-energy photon radiation.[6]

The experimental set-up for measuring the beam quality $TPR_{20,10}$ is shown in Fig. 2. And the reference conditions of measurements are given in Table 2.

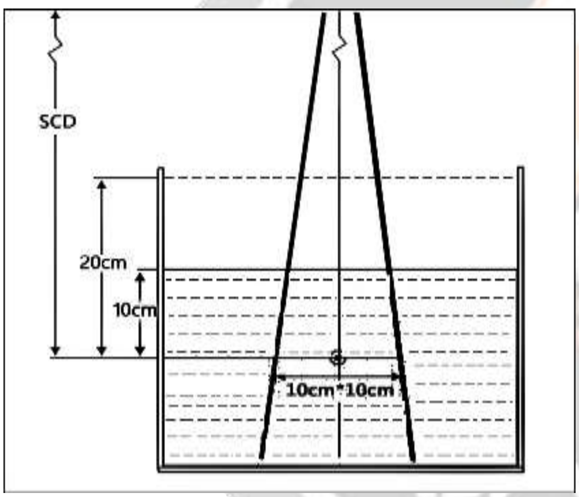

Figure -1.1: Schematic diagram of experimental set-up

Figure -1.2: experimental set-up for the determination $TPR_{20,10}$ and absorbed dose/MU

Table -2: Reference conditions for the determination of photon beam quality ($TPR_{20,10}$)

Influence quantity	**Reference value or reference characteristics**
Phantom material	Water
Chamber type	Cylindrical
Measurement depths	20 g/cm2 and 10 g/cm2
Reference point	on the central axis
Position of the reference For chambers	at the point of the chamber measurement depths
Source to Chamber Distance (SCD)	100 cm
Field size at SCD	10 cm × 10 cm

2.2 DETERMINATION OF ABSORBED DOSE UNDER REFERENCE CONDITIONS

The absorbed dose to water at the reference depth z_{ref} in water, in a photon beam of quality Q was calculated using the following equation: [6–8]

$$D_{W,Q} = M_1 \times K_{T,P} \times K_e \times K_{pol} \times K_s \times N_{D,W,Q_0} \times K_{Q,Q_0} \quad \ldots\ldots (1)$$

Where, M_1 is the reading of the dosimeter with the reference point of the chamber positioned at z_{ref}. $K_{T,P}$ is the correction for the influence of temperature and pressure, K_e is the electrometer calibration correction, K_{pol} is the polarity effect and K_s is the factor for ion recombination. N_{D,W,Q_0} is the calibration factor in terms of absorbed dose to water for the dosimeter at the reference quality Q_o, and K_{Q,Q_0} is a chamber specific factor which corrects for the difference between the reference beam quality Q_o and the actual quality being used, Q. $K_{Q,Q_0}$is obtained from the table 6.111 given in TRS-398, (2006) as a function of beam quality $TPR_{20,10}$ (Interpolation was applied for the necessary cases).

Table – 3: Reference conditions for the determination of absorbed dose to water in high energy photon beams

Influence quantity	Reference value or reference characteristics
Phantom material	Water
Chamber type	Cylindrical
Reference point of the chamber	On the central axis at the centre of the cavity volume
Position of the reference point	At the measurement depth z_{ref}=10cm
SSD (Source to Surface Distance)	100 cm
Field size	10 cm × 10 cm

3. RESULT AND DISCUSSION

3.1 BEAM QUALITY $TPR_{20,10}$ MEASUREMENT

$TPR_{20,10}$ was measured for a field size of 10 cm x 10 cm and by keeping SCD fixed at 100 cm. Over the period of 36 months we found that $TPR_{20,10}$ for 6 MV photon beam was 0.67 corresponding K_{Q,Q_0} was 0.9937 and $TPR_{20,10}$ for 15 MV photon was 0.76 corresponding K_{Q,Q_0} was 0.976. Measured values showed that the values of beam quality $TPR_{20,10}$ are very much consistent; actually values never changed when the values are rounded to two decimal points. There may be changes after two decimal points which are not significant since TRS-398 tabulated the values for two decimal points only. In case of finding the values of K_{Q,Q_0} for 6MV photon beam it was required to interpolate the K_{Q,Q_0} values 0.995 and 0.993 corresponding to the $TPR_{20,10}$ values 0.65 and 0.68 respectively since our calculated value of $TPR_{20,10}$ was 0.67. From these measured values it can be said that the Beam quality $TPR_{20,10}$ remains constant for a specific beam and needless to calculate each time of measuring absorbed dose but using the value from previously measured one.

3.2 OUTPUT DOSE/MU MEASUREMENT

The absorbed dose to water at the reference depth z_{ref} in water, in a photon beam of quality Q was calculated setting Reference point of the chamber on the central axis at the centre of the cavity volume; Position of the reference point At the measurement depth z_{ref}=10cm; SSD kept fixed at 100cm and the field size was 10 cm × 10 cm. The output dose at depth 10 cm was calculated using equation (1) and then divided it by the relative value of the output at the same depth (D_{10cm} value) obtained from the PDD curves.[9] The measured values of absorbed doses at Dmax (cGy/MU) are shown in graph 1.

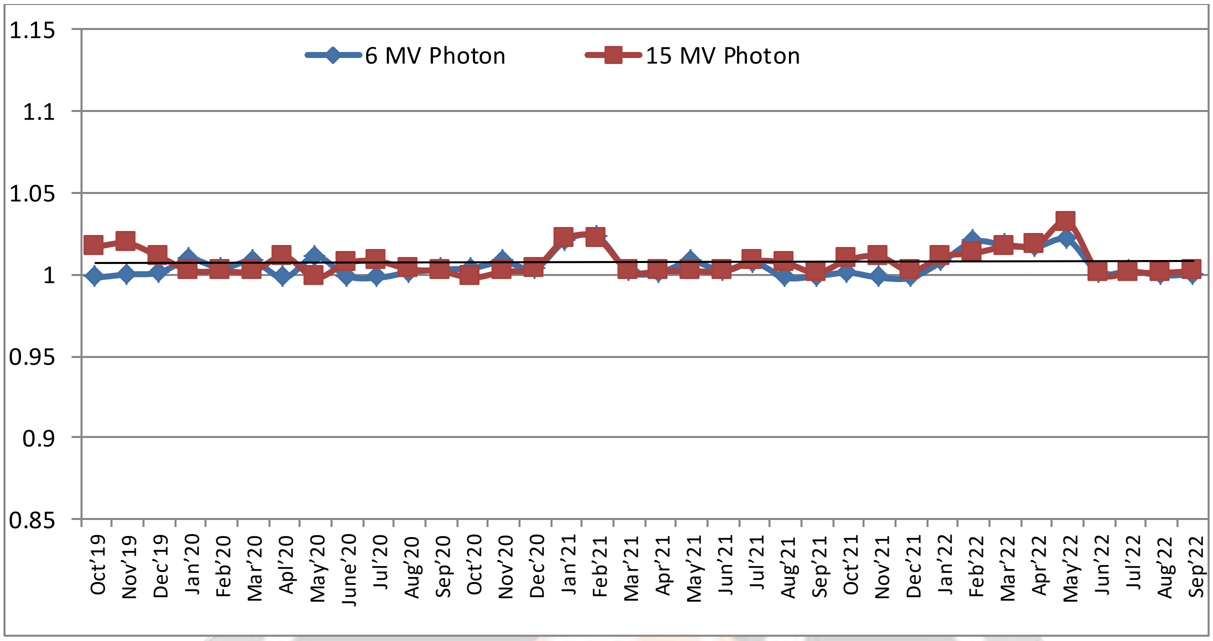

Chart -1: The measured values of absorbed doses at D_{max} (cGy/MU)

The measured output dose/MU was found in between 0.998 to 1.023 cGy for 6MV photon beam and 0.998 to 1.032 cGy for 15MV photon beam at D_{max} position. Here, the dosimetric data of the linac were evaluated over a period of 36 months for 6 MV and 15 MV energies. Routine beam Output Dose/MU consistency checks were designed for photon beams with field size 10cm*10cm, source to surface distance 100 cm. The Ion-chamber was placed at a depth of 10 cm. The dose/MU for all radiation beams was maintained within the tolerance 2% over the period of 36 months. In January 2021 first time linac showed increasing trend of cGy/MU and cross the tolerance. Therefore, in February 2021 the machine tuned of the monitor unit for getting 1 cGy/MU at the D_{max} position under water. Again in May 2022 machine tuned of since the machine crossed it cGy/MU tolerance.

4. CONCLUSION:

The present work has highlighted the results of QA measurements and their efficacy in evaluating the photon beam outputs. Beam quality TPR20,10 and beam output ware determined in accordance with the IAEA Technical Report Series (TRS-398). Generally machine tuned to deliver 1cGy/MU at SSD 100 cm technique at D_{max} for all the available photon energy. All the measurements were carried out using 1D water phantom. The reference conditions for calculating the absorbed dose to water are, such as the geometrical arrangement (distance and depth), the field size, the material and dimensions of the irradiated phantom, and the ambient temperature, pressure and relative humidity were take into account properly and the correction factors were taken into account. Absorbed dose to water at the depth of dose maximum (D_{max}) Photon Beam was found to be in-between 1.023 cGy/MU to 0.998 cGy/MU for 6 MV photon beam and 1.032 cGy/MU to 0.998 cGy/MU for 15 MV photon beam. The dose/MU for all radiation beams was maintained within 2% accuracy over the period of 36 months. When beam output increased over 2% trend over a period, which indicated that machine need tuning. Tuning of the monitor unit to achieve standard value was carried out twice. Before tuning output doses were measured several times and after tuning the output dose was also measured several times so that no mistakes could take place. These simple QA procedures mentioned in this paper could be useful in all radiotherapy departments for studying beam consistency.

5. ACKNOWLEDGEMENT

The authors also would like to thank all the personnel of the Institute of Nuclear Medical Physics (INMP), for the necessary support of this work.

6. REFERENCE

[1] Ferlay J, Ervik M, Lam F, Colombet M, Mery L, Piñeros M, Cancer, (n.d.). https://www.who.int/news-room/fact-sheets/detail/cancer (accessed September 21, 2022).

[2] K.R. Mani, M.A. Bhuiyan, M.S. Rahman, S.M.A. Islam, Open beam dosimetric characteristics of True Beam medical linear accelerator with flattening filter (WFF) and flattening filter free (FFF) beam, Pol. J. Med. Phys. Eng. 24 (2018) 79–89. https://doi.org/10.2478/pjmpe-2018-0011.

[3] S.C. Vaz, J.A. Adam, R.C. Delgado Bolton, P. Vera, W. van Elmpt, K. Herrmann, R.J. Hicks, Y. Lievens, A. Santos, H. Schöder, B. Dubray, D. Visvikis, E.G.C. Troost, L.-F. de Geus-Oei, Joint EANM/SNMMI/ESTRO practice recommendations for the use of 2-[18F]FDG PET/CT external beam radiation treatment planning in lung cancer V1.0, Eur. J. Nucl. Med. Mol. Imaging. 49 (2022) 1386–1406. https://doi.org/10.1007/s00259-021-05624-5.

[4] P. Diez, E.G. Aird, Quality assurance in radiotherapy, (2012). https://doi.org/10.1093/med/9780199696567.003.0022.

[5] R. Ravichandran, J.P. Binukumar, C.A. Davis, K. Krishnamurthy, S.S. Sivakumar, Evaluation methods for detecting changes in beam output and energy in radiation beams from high-energy linear accelerators, J. Med. Phys. Assoc. Med. Phys. India. 32 (2007) 92. https://doi.org/10.4103/0971-6203.35720.

[6] Pedro Andreo, David T Burns, Klaus Hohlfeld, M Saiful Huq, Tatsuaki Kanai, Fedele Laitano, Vere Smyth,, Stefaan Vynckier, Absorbed Dose Determination in External Beam Radiotherapy, (2006). https://www.iaea.org/publications/5954/absorbed-dose-determination-in-external-beam-radiotherapy (accessed September 21, 2022).

[7] M. J, A. P, G. E, M. O, M. A, R. M, Ionization chamber dosimetry of proton beams using cylindrical and plane parallel chambers. Nw versus Nk ion chamber calibrations, Phys. Med. Biol. 40 (1995). https://doi.org/10.1088/0031-9155/40/7/002.

[8] S. Akter, R. Khatun, F. Uddin, A.N. Monika, M. Parvej, N. Sultana, A. Hasnat, S. Alim, M. Ahasan, Dosimetry Measurement of Medical Linear Accelerator and Assessment the Authentication it with Machine Records, (2022) .

[9] Development of spreadsheet for rapid assessment of therapeutic radiation dose delivery with electron and photon beams at various energies, J. Cancer Prev. Curr. Res. Volume 13 (2022). https://doi.org/10.15406/jcpcr.2022.13.00479.