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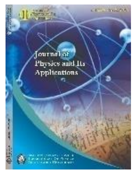

Assessment of Measured and Calculated Dose Rate of Co-60 Teletherapy Machine: 06 Years' Experience at NORIN Nawabshah, Pakistan

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A B S T R A C T

It is essential to determine the absolute output dose of Co-60 source in the radiation treatment periodically. It is because overdosage may cause radiation hazards whereas under dosage may lead to the unsatisfactory treatment of cancer. The current study is focused on the consistency of monthly dose output verification of the cobalt-60 Teletherapy unit which should be within ±2% as per international standards. In the present study, the measured and calculated dose rate of the Co-60 teletherapy unit at Nuclear Medicine Oncology and Radiotherapy Institute Nawabshah (NORIN) for the last 6 years is analyzed. The dose measurement was done in water phantom 30×30×30 cm3 at 80 cm Source to Surface Distance with 5cm depth by using calibrated electrometer and PTW ionization chamber. The measured output dose rate obtained by actual dosimetry is within ±2% of the dose rate calculated by the decay method and the deviation lies within the permissible limit as prescribed by International Atomic Energy Agency (IAEA), International Commission on Radiological Units and Measurement (ICRUM)and American Association of Physicists in Medicine (AAPM). The variation in measurements obtained is within the tolerable limits according to standard protocols and codes. Thus, our study shows a homogenous trend in the dose rate of the Co-60 teletherapy machine.

1. Introduction

Radiation therapy is a major cancer treatment modality used either alone or in conjunction with other treatment methods [1]. The main focus in radiotherapy is maximizing the dose to tumor cells while keeping the dose to surrounding normal tissues as low as possible [2]. There are several types of radiation being used for treatment i.e., photons, electrons, protons, and heavy ions. Modern radiation therapy is using high energy photons beams produced by linear accelerators along with Co-60 teletherapy units. The treatment of cancer implies the killing of malignant cells using ionizing radiation [3].

The purpose of radiotherapy involves the treatment of cancer as well as the minimization of complications that can arise in normal tissues. To fulfill this purpose, accurate radiation doses are required that entirely depend upon the measurement of the dose rate from the source [4]. There is a tolerance of ±2% in the source dose rate measurement according to protocols [5-6] and the same tolerance has been endorsed by other authors too [7-8]. According to IAEA and ICRU, the tolerance in the prescribed dose is ±5%. Many strategies have been devised to confine the tumor doses well within the limit recommended by ICRU [9-10].

Dosimetry is an essential component of Quality Assurance of radiation-producing machines/sources. It is one of the systematic and planned actions that are required to provide quality healthcare service [11]. This study was conducted on a Co-60 radiotherapy machine for determination of its depth doses in a water phantom at 80 cm SSD at depth of 5 cm as per protocols of IAEA [12-13].

The variation in absorbed dose can be observed by changing SSD, depth, and Field Size [14]. Water phantoms are used for these measurements because it is not possible to perform depth dose measurements on the patients [15]. Due to the tissue equivalence of water, the measurements recorded in water can be approximated to the dose delivered to the patient during the treatment.

The NORIN Cancer Hospital Nawabshah is a comprehensive healthcare facility. It deals with the diagnosis, treatment, and research of malignant tumors. It was established to adopt the latest research methodologies for cancer management. A cobalt-60 teletherapy machine is used for external beam radiotherapy for different cancer treatments in the radiotherapy department of NORIN Nawabshah [16]. This research aims to compare the measured and calculated absolute output dose of the Co-60 teletherapy machine for the period of 06 years at this institute.

2. Methods

Best Theratron's Phoniex teletherapy machine of Atomic Energy Company Limited (AECL) Canada is installed at Atomic Energy cancer hospital Nawabshah (NORIN) Pakistan since 2012. The beam output measurement is carried out every 2 years by Secondary Standard Dosimetry Laboratory Pakistan (SSDL) as per the requirement of the Pakistan Nuclear Regulatory Authority (PNRA). Monthly dose verification is routinely being performed since installation. For routine dose measurements, PTW 0.6 cc ion chamber (Model 30013) was used along with a Sun Nuclear 1D PC electrometer. The radiation dose was measured in 30×30×30 cm^3 water at 80 cm SSD and 5cm depth with a 10 x 10 cm^2 field size. TRS-398 (IAEA) protocol is being followed for absolute dosimetry [17]. The ionization chamber and electrometer assembly are calibrated every two years from Secondary Standard Dosimetry Laboratory (SSDL) PINSTECH Islamabad at +400 V polarity voltages, 1013.25 kPa pressure, and 200 C temperatures. The same parameters are used for routine dosimetry too [18].

The radiation dose for 1 minute of ON time at reference depth is calculated using the equation:

$$Dose\ in\ water = M_R \times K_{pol} \times K_S \times K_q \times N_{DW} \times K_{TP} \tag{1}$$

where MR is the electrometer reading, Kpol is the polarity correction factor while Ks is the ion recombination factor. Both are considered a unity because polarity and applied high voltage are kept the same as the parameters on which the chamber was calibrated. The Quality Factor KQ is also taken as unity for Co-60 gamma rays. NDW is the calibration factor for water absorbed dose of a given electrometer and thimble chamber. KTP is the correction factor of pressure and temperature, $(273.2+T) / (273.2+ T_o) \times P_o/P$ where P_o and T_o are the standard numbers (generally 20°C and 101.325 KPa).

$$D_{cal} = D_o e^{\frac{-0.693\,t}{T_{1/2}}} \tag{2}$$

Where $T_{1/2}$ is the half-life of the Co-60 source and t is the time elapsed after beam output measurement. Is the measured dose from recent SSDL measured dose output.

$$\%\,Difference = 100 \times \frac{(D_{measured} - D_{cal})}{D_{cal}} \tag{3}$$

The dose measurement data has been recorded for the last 5 years since 2016. The present study is the analysis of this data.

3. Results and Discussion

The measured dose and expected output (calculated through the decay method) are tabulated in Table 1. It is visible from tabulated data that the percentage error calculated during each year has been always less than ±2% which is reliable by standard protocols. Graphical representation has been shown in Fig. 1 and Fig. 2 explain measured and calculated outputs for 6 years. Fig. 3 shows the percent error of measured and calculated outputs. The blue bars in Fig. 3 represent the positive while the red bars represent negative errors.

It is pertinent to know that the radiation dose being delivered to the patient must equate to the prescribed dose. The only way to know that for sure is to measure the absorbed dose regularly. AAPM TG 40 recommends monthly dose verification for the Cobalt-60 machine with an acceptable dose difference of ±2% from the calculated dose [19].

Following is the reported literature for Best Theratron Phoenix Co-60 teletherapy units, graphically summarized in Fig. 4. This figure illustrates the error ranges between measured and calculated outputs of previously reported results. The factors like dosimetry setup inaccuracy, physical conditions of temperature and pressure, positioning of beam dosimeters, and calibration differences contribute to these small-scale justified errors.

Table 1. Actual, Expected Decayed outputs with Percentage Error of Co-60 machine (NORIN)

Year	Month	Quarterly Dosimetry	Calculated Dose Rate D_{cal} (Gy/min)	Measured Dose Rate $D_{measured}$ (Gy/min)	Dose Difference	Percentage Error	Yearly Average Error
2016	January	01	1.428	1.400	0.019	1.96	1.71
	April	02	1.377	1.351	0.018	1.89	
	July	03	1.334	1.32	0.010	1.05	
	October	04	1.28	1.255	0.019	1.95	
2017	January	05	1.252	1.231	0.016	1.68	1.38
	April	06	1.225	1.220	0.004	0.41	
	July	07	1.191	1.173	0.015	1.51	
	October	08	1.147	1.125	0.019	1.92	
2018	January	09	1.093	1.085	0.007	0.73	1.20
	April	10	1.0658	1.0597	0.005	0.57	
	July	11	1.026	1.011	0.014	1.46	
	October	12	0.99	0.9700	0.020	2.00	
2019	January	13	0.962	0.9810	-0.019	-1.98	1.71

	April	14	0.9399	0.9537	-0.014	-1.47	
	July	15	0.9041	0.8901	0.015	1.55	
	October	16	0.8713	0.8551	0.018	1.86	
	January	17	0.8474	0.8627	-0.018	-1.81	
2020	April	18	0.8200	0.8363	-0.019	-1.99	1.56
	July	19	0.7955	0.8038	-0.010	-1.04	
	October	20	0.7678	0.7572	0.013	1.38	
	January	21	0.7440	0.7560	-0.016	-1.61	
2021	April	22	0.7200	0.7160	0.005	0.56	1.47
	July	23	0.6880	0.6760	0.017	1.74	
	September	24	0.6551	0.6423	0.019	1.95	

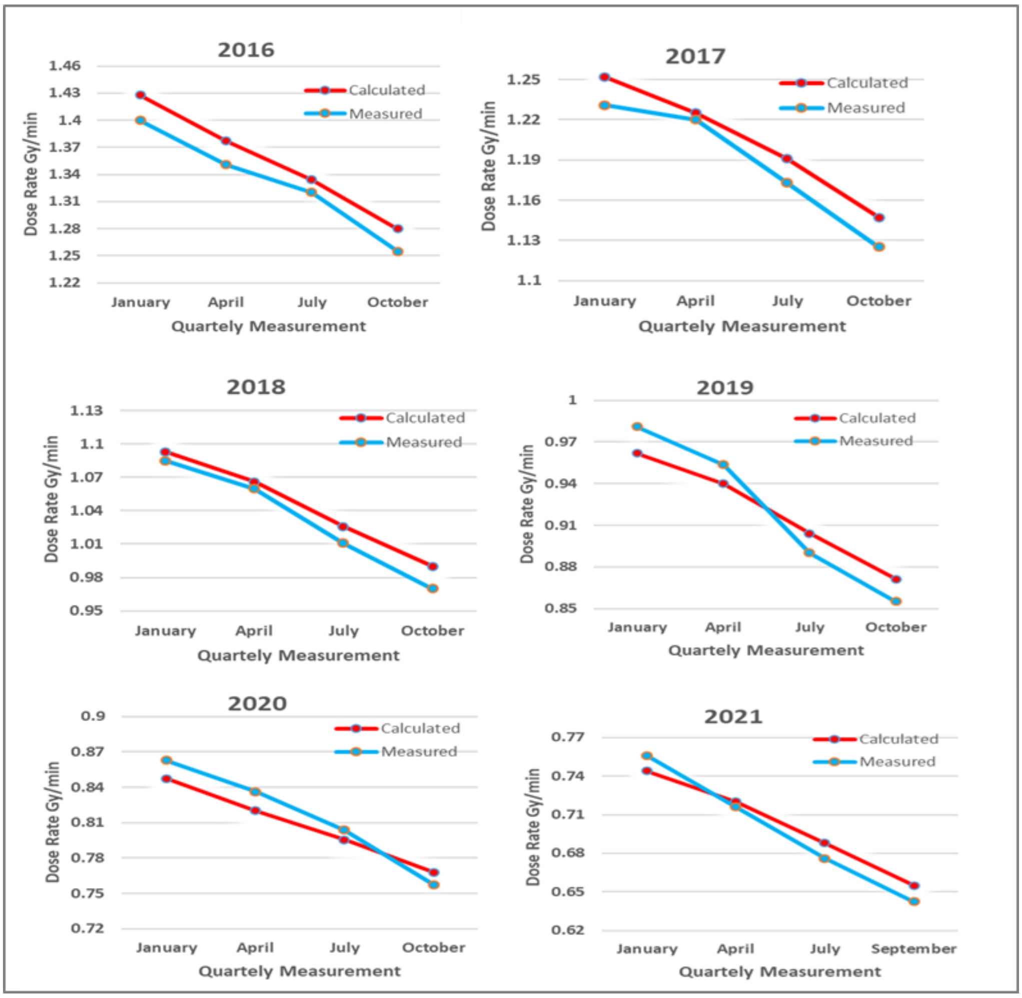

Fig.1: Plots for the output of the Co-60 Teletherapy machine for comparing Measured and Calculated outputs for six years of data analysis.

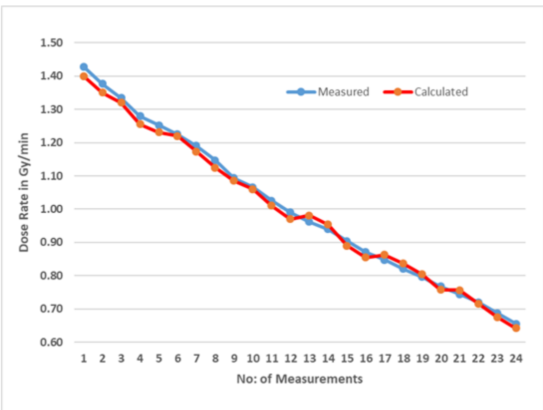

Fig.2: Measured and Calculated outputs in Gy/min for Co-60 Theratron, AECL Canada.

Baba M.H. et al. reported a minimum and maximum dose difference of -1.65% and +0.66% respectively [4]. SA Memon reported a slightly higher value of 2.08% and +2.48% minimum and maximum dose difference for the same model of a machine [20]. Another study conducted by Acharya NP shows -1.34% and 1.78 output rates as Minimum and Maximum respectively [21]. AECH-NIMRA in a separate study with a larger data volume concluded the -1.49% and +2.25% for the same model machine [22].

The minimum and maximum percentage errors for the current study (AECH-NORIN) are -1.98% and +2.00 % are graphically represented in Fig. 4. In absolute values, these are 0.56 and 2% differences. The dose difference averaged over the whole year has also been within ±2%. More studies are required for a good comparison.

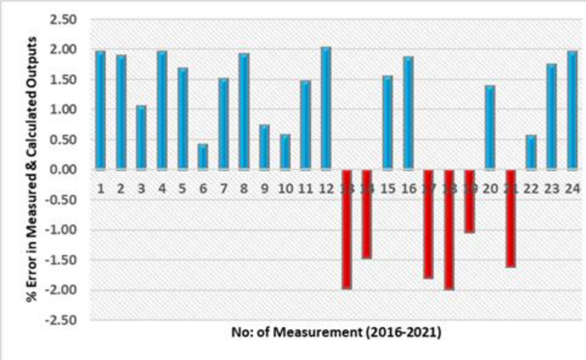

Fig.3: Percent Error in Measured and Calculated decayed output for Theratron Phoenix Co-60 machine.

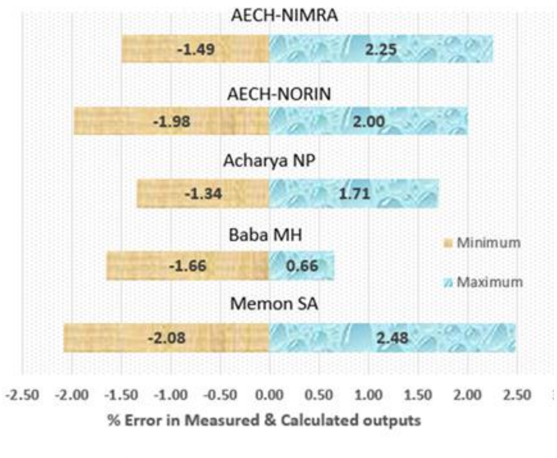

Fig.4: Ranges of Errors in Measured and Calculated outputs for previous and current studies of Co-60 Teletherapy Machines.

4. Conclusion

The dose verification of Co-60 teletherapy machine output was carried out on monthly basis for the last 6 years and the difference between absorbed and calculated doses was recorded. It is concluded that the difference between measured and calculated doses has always been within 2% as required by international protocols. It can also be concluded that the dose delivered to the patients is the dose prescribed by the oncologist with a reasonable degree of accuracy.

5. Conflict of Interest

The authors declare that they have no conflict of interest.

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Author Contribution

Mr. Muhammad Waqar (Head-MPD, NORIN) is the lead contributor to the article. Other Authors contributed to proofreading and approving the final version of the paper.

References

[1] I. Kunkler, C. K. Bomford, and I. H. Kunkler, “Effects of radiation on normal tissues,” Walter Miller’s Textb. Radiother., 296–306, (2003).

[2] I. A. E. Agency, "Radiation protection in the design of radiotherapy facilities," Int. At. En. Agency, (2006).

[3] K. N. Prasad, W. C. Cole, and G. M. Haase, “Radiation protection in humans: extending the concept of as low as reasonably achievable (ALARA) from dose to biological damage,” Br. J. Radiol., 77, 914, 97–99, (2004).

[4] M. M. H. Baba, M. Mohib-ul-Haq, and M. A. A. Khan, “Dosimetric consistency of Co-60 teletherapy unit-a ten years study,” Int. J. Health Sci. (Qassim)., 7, 1, 15, (2013).

[5] G. J. Kutcher et al., “Comprehensive QA for radiation oncology: report of AAPM radiation therapy committee task group 40,” Med. Phys., 21, 4, 581–618, (1994).

[6] HPA, “A code of practice for the dosimetry of x-ray and caesium-137 and cobalt-60 gamma-ray beams,” Phys. Med. Biol., 9, 4, 457–463, (1964).

[7] W. F. Hanson, R. J. Shalek, and P. Kennedy, “Dosimetry quality assurance in the US from the experience of the Radiological Physics Center,” (1991).

[8] D. I. Thwaites, B. J. Mijnheer, and J. A. Mills, “Quality assurance of external beam radiotherapy,” Radiat. Oncol. Phys. a Handb. Teach. students. Vienna Int. At. Energy Agency, 407–450, (2005).

[9] A. Wambersie, J. van Dam, G. Hanks, B. J. Mijnheer, and J. J. Battermann, “What accuracy is needed in dosimetry,” (1994).

[10] D. I. Thwaites, “The significance and impact of dosimetry audits in radiotherapy,” (2010).

[11] A. Brahme, “Dosimetric precision requirements in radiation therapy,” Acta Radiol. Oncol., 23, 5, 379–391, (1984).

[12] W. H. Organization, “Absorbed dose determination in external beam radiotherapy. An international code of practice for dosimetry based on standards of absorbed dose to water,” (2004).

[13] M. S. Huq, “Absorbed dose determination in external beam radiotherapy: an international code of practice for dosimetry based on standards of absorbed dose to water,” (2006).

[14] S. A. Memon et al., “Analysis and verification of percent depth dose and tissue maximum ratio

for co-60 gamma ray beam," Worl. App. Sci. J., 33, 1, 109–113, (2015).
[15] R. D. Praveenkumar, K. P. Santhosh, and A. Augustine, "Estimation of inhomogeneity correction factors for a Co-60 beam using Monte Carlo simulation," J. Cancer Res. Ther., 7, 3, 308, (2011).
[16] M. Waqar, M. Shahban, Q. Soomro, and M. N. Abro, "Institution-based assessment of cancer patients treated by external beam radiotherapy in the rural area of Sindh, Pakistan: Five years of data analysis," Middle East J. Cancer, 9, 3, 217–222, (2018).
[17] M. C. Lizuain, D. Linero, and C. Picon, "Evaluation of codes of practice: IAEA TRS-277, TRS-381, TRS-398 and AAPM TG-51 in high photon and electron beams," (2002).
[18] P. N. R. Authority, "PNRA Regulations on radiation protection (PAK/904)," Islam. Pakistan Nucl. Regul. Athority, (2004).
[19] Gerald J. Kutcher et al., "Aapm Tg 40," Medical Phys., 21, 4, 581–618, (1994).
[20] S. A. Memon, N. A. Laghari, F. H. Mangi, M. A. Jafri, M. Raza, and M. A. Abbasi, "Dosimetric Conformity of Cobalt-60 (Co 60) Beams."
[21] N. P. Acharya, T. R. Lamichhane, and B. Jha, "Quality Assurance with Dosimetric Consistency of a Co-60 Teletherapy Unit," J. Nepal Phys. Soc., 4, 1, 88–92, (2017).
[22] S. A. Memon, A. A. Cheema, N. A. Laghari, and F. H. Mangi, "Dose measurement of cobalt-60 radiotherapy beams in treatment fields," J. Ayub Med. Coll. Abbottabad, 26, 3, 279–282, (2014).