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Dosimetric Conformity of Cobalt-60 (Co^{60}) Beams

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Abstract- Objective: The radiation dosimetry is the output measurement of radiation generating source/ machine and its ambition is to ensure that the teletherapy units' outputs are within limits. In the current article, the dosimetry of Cobalt-60 (Co^{60}) teletherapy units at Nuclear Institute of Medicine and Radiotherapy (NIMRA), Jamshoro Pakistan was studied. As Co^{60} is undergo decay process, the output (dose rate) also decreases, therefore regular output measurement is obligatory to deliver appropriate dose to patient. The over dosage leads to hazards of radiation and under dosage may cause inadequate cancer treatment. This study highlights constancy between actual output and output acquired using decay method.

Material and Methods: In the present study, the evaluation and comparison in the measurement of actual dose rate and expected output using decay method of Co60 teletherapy units has been done.

Results: The evaluation and comparison of the values of output obtained by the two methods (actual and the expected outputs by decay method) shows constancy. Most of the values obtained by actual dosimetry are within ±2% of the expected measurements.

Conclusions: The variation in measurements obtained by two methods is within the tolerable limits according to standard protocols and codes. Thus our study shows a homogenous trend in dose rate and a better patient dose delivery to avoid over or under dosage.

Keywords-*Radiotherapy, Medium, Ionization Chamber, Cobalt-60 (Co^{60}), Dosimetry, Output, Dosimetric Constancy, Radioisotope*

I. Introduction

For treating cancer, gamma ray emitting source Cobalt-60 (${}_{27}Co^{60}$ or simply Co^{60}) is used [1- 3]. By the emitting beta particle, Cobalt-60 decays to Nickel-60 (${}_{28}Ni^{60}$). The excited nickel nucleus emits 1.17 MeV and 1.33 MeV gamma ray photons simultaneously [1, 3- 5]. Due to this decays of Co^{60}, activity decreases also and this decreasing activity requires periodic source replacement in teletherapy unit. Although in modern radiotherapy, Linear Accelerator (LINAC) has replaced Co^{60} teletherapy machine to some extent due to this reason[4], but simplicity in maintenance and reliability of Co^{60} teletherapy machine as compared to modern LINAC, it is still in extensive use globally [1, 4].

The goal in treating patients with radiation is to treat or control the deadly disease while minimizing normal tissues complications. To achieve this, the delivery of radiation dose must be accurate which solely depends on accurate dose rate measurement of the source [1]. The protocols and codes [6-13] have proposed ±2% uncertainty in dose rate measurement which was endorsed by documents/articles [14-18] and overall limit of ±5% of the prescribed dose has been recommended by International Commission on Radiation Units and Measurement (ICRU) [19], International Atomic Energy Agency (IAEA) [20-22] and other researchers [23- 25]. Many steps are involved to deliver the dose to the target volume in a patient with much better accuracy (less than ±5%) to achieve the recommendations of ICRU [1]

Dose rate measurement or dosimetry of any radiation generating device/source is an integral part of a quality assurance (QA) program which consists of all those systematic or planned actions necessary to assure the given requirements for quality health care services [1, 26, 27].

Our study aims that the dose rate must satisfy the criteria given in ICRU 24 [19] for accurate dose delivery to cancer patients.

As absorbed dose depends on factors of photon energy, Source to Surface Distance (SSD), field size & depth and by varying one of these values, the change in absorbed dose can be observed [28, 29].

Due to impossibility of the dose rate measurement in the real patient [30], water phantom or equal medium are being used since birth of patient's treatment with radioisotopes [2], then be applied in calculation for an actual patient treatment [31-34].

II. Material and Methods

The dosimetry of Theratron 780c of Atomic Energy Company Limited (AECL) Canada and GWXJ80 of National Power Institute Company (NPIC) China installed at Nuclear Institute of Medicine and Radiotherapy (NIMRA) Jamshoro Pakistan was carried out using equipments:

1. Dosimetry System (Farmer Electrometer NE 2570 calibrated with NE 2571, 0.6cc Thimble Chamber)

2. Water phantom (30x30x20 cm^3)

3. Aneroid Barometer

4. Thermometer

The methodology consisted of:

1. The measurements of doses (output) were done with calibrated dosimetry system for 10 x 10 cm^2 field size at 80 cm (centimeter) SSD by using IAEA, TRS-398 protocol [35]. The calibrated ionization chamber was set at reference depth of 5 cm in water phantom. Although along with water phantoms, phantoms of other materials are also available for dosimetry of the teletherapy units but due to equality in density with human tissue, the water has superiority on others [29].

2. IAEA's TRS-398 (2000) protocol [35] was used to obtain the dose rate at reference depth using the following formula:

$$\text{Output (Dose rate in water)} = M_R \times K_{Pol} \times K_S \times K_Q \times N_{DW} \times K_{TP}$$

M_R = Electrometer reading

$$K_{Pol} = \frac{|M_+| + |M_-|}{2M}$$

K_{Pol} = Change in polarity factor to correct the ionization chamber response on change of polarizing voltage taken as 1 (as the electrometer used at NIMRA Jamshoro Pakistan has no voltage settings)

$|M_+|$ = Electrometer reading at voltage $+V_1$

$|M_-|$ = Electrometer reading at voltage $-V_2$

K_S = Ion recombination correction factor to take two electrometer readings on two voltage settings, and was taken as 1 (due to no voltage settings in the electrometer used at NIMRA Jamshoro Pakistan) and

$$K_S = \left(\left(\frac{V_1}{V_2}\right)^2 - 1\right) \Big/ \left(\left(\frac{V_1}{V_2}\right)^2 - \left(\frac{M_1}{M_2}\right)^2\right)$$

K_Q = Energy correction factor and for Co-60 was taken as 1.

N_{DW} = Calibration factor of electrometer and ionization chamber for absorbed dose to water.

K_{TP} = Temperature & Pressure correction factor and

$$K_{TP} = \frac{273.2 + T}{273.2 + T_o} \times \frac{P_o}{P}$$

Where P_o and T_o are the reference values of pressure and temperature respectively and were taken as 101.3 kPa (kilopascal) and 20° C (Celsius).

3. As the chamber was kept at reference depth of 5 cm so the output obtained from the above equation would be at depth of 5 cm. In order to get the output at D_{max}, the obtained output results were divided by percent depth dose (at 5 cm depth).

4. Due to decay of Co-60, the dose rate multiplying with decay factor using following formula, the expected output was obtained.

$$D_f = D_i \times e^{\frac{-0.693 \times t}{T_{1/2}}}$$

D_f = Final or current dose rate of the source

D_i = Initial of previous dose rate of the source

t = Time difference (in days) between two dose rate measurement

$T_{1/2}$ = Half life of source (Half life of Co-60 is 1925 days approximately)

5. The percentage error for event of dosimetry had been calculated by comparing the output obtained by the two processes (actual dosimetry and decay method).

6. The dosimetric data of the units was taken at the interval of 3.5±0.5 months.

III. RESULTS

The actual output measured and expected output calculated using the decay method are showed in Table 1 and their graphically representation has been shown in Fig. 1 and 2. Fig. 3 explains about %age error in actual, expected decayed outputs for the two teletherapy units of NIMRA Jamshoro Pakistan.

TABLE I. ACTUAL, EXPECTED DECAYED OUTPUTS IN GY/MIN AND % ERROR FOR THERATRON 780C, AECL CANADA AND GWXJ80, NPIC CHINA.

Unit	Sr. No.	Actual Output AO Gy/min	Expected Output from previous dose rate measurement EO Gy/min	% Error = $\frac{EO - AO}{EO} \times 100$
Theratron 780c AECL Canada	1	0.5807	0.5770	-0.64
	2	0.4985	0.4909	-1.56
	3	0.4837	0.4841	+0.09
	4	0.4716	0.4776	+1.26
	5	0.4740	0.4643	-2.08
	6	0.4431	0.4519	+1.95
	7	0.4164	0.427	+2.48
	8	0.4076	0.4009	-1.67
	9	0.3840	0.3917	+1.97
	10	0.3683	0.3688	+0.13
GWXJ80 NPIC China	1	1.5547	1.5319	-1.49
	2	1.5144	1.4968	-1.18
	3	1.4371	1.4506	+0.93
	4	1.4100	1.4144	+0.31
	5	1.3286	1.3516	+1.7
	6	1.2265	1.2284	0.15
	7	1.1632	1.1795	+1.39
	8	1.1429	1.1296	-1.17
	9	1.0782	1.103	+2.25
	10	1.0241	1.0276	0.34

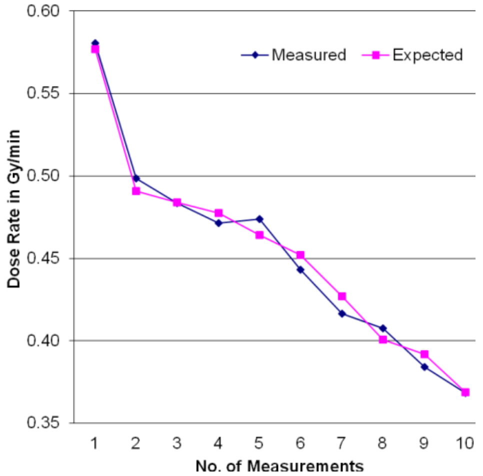

Figure 1. Actual and expected decayed outputs in Gy/min for Theratron 780c, AECL Canada.

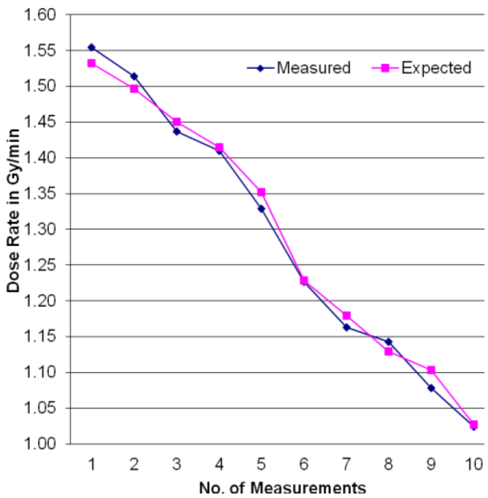

Figure 2. Actual and expected decayed outputs in Gy/min for GWXJ80, NPIC China.

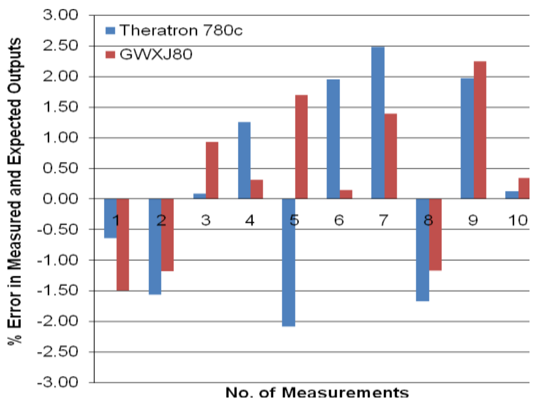

Figure 3. %age errors in actual and expected decayed outputs for Theratron 780c, AECL Canada and GWXJ80, NPIC China

IV. DISCUSSIONS

Although the current study is exposing an important topic and unique & distinctive in nature but only slight work has been done (Baba MH et al.) [1] yet who reveals that the minimum and maximum %age errors in actual and expected output as -1.6568% and +0.655% respectively whereas the current study shows the minimum and maximum %age errors in actual and expected outputs slightly higher as -2.08% & +2.48% for Theratron 780c and -1.49% & +2.25% for GWXJ80 respectively. The minimum and maximum %age errors are graphically represented in Fig. 4.

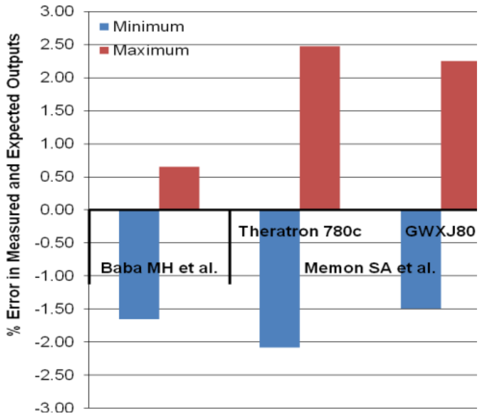

Figure 4. Graphically representation of %age errors in actual and expected decayed outputs for previous and current studies (for Theratron 780c, AECL Canada and GWXJ80, NPIC China).

Even very little higher variations (>±2%) has been found in some measurements but no significant deviation was noticed in nearly all of measurements. Most of variations promise the standard of less than ±2%, which is according to the related protocols/documents [6-18] which projected to achieve an overall ±5% dosimetric uncertainty as per mentioned protocols/literature [19-25].

V. CONCLUSIONS

The comparison of obtained output by using absolute dosimetry and expected output using decay formula shows deviation within acceptable limit of ±2% in the largest piece of measurements. This current study shows continuous tendency of the constancy and uniformity in measured output which confirms the accuracy in patient dose calculation. Authors suggested that more study may be conducted for verification of current and related study [1].

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