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Dosimetric Consistency of Co-60 Teletherapy Unit- a ten years Study

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Abstract

Objective: The goal of the Radiation standards and Dosimetry is to ensure that the output of the Teletherapy Unit is within ±2% of the stated one and the output of the treatment dose calculation methods are within ±5%. In the present paper, we studied the dosimetry of Cobalt-60 (Co-60) Teletherapy unit at Sher-I-Kashmir Institute of Medical Sciences (SKIMS) for last 10 years. Radioactivity is the phenomenon of disintegration of unstable nuclides called radionuclides. Among these radionuclides, Cobalt-60, incorporated in Telecobalt Unit, is commonly used in therapeutic treatment of cancer. Cobalt-60 being unstable decays continuously into Ni-60 with half life of 5.27 years thereby resulting in the decrease in its activity, hence dose rate (output). It is, therefore, mandatory to measure the dose rate of the Cobalt-60 source regularly so that the patient receives the same dose every time as prescribed by the radiation oncologist. The under dosage may lead to unsatisfactory treatment of cancer and over dosage may cause radiation hazards. Our study emphasizes the consistency between actual output and output obtained using decay method.

Methodology: The methodology involved in the present study is the calculations of actual dose rate of Co-60 Teletherapy Unit by two techniques i.e. Source to Surface Distance (SSD) and Source to Axis Distance (SAD), used for the External Beam Radiotherapy, of various cancers, using the standard methods. Thereby, a year wise comparison has been made between average actual dosimetric output (dose rate) and the average expected output values (obtained by using decay method for Co-60.)

Results: The present study shows that there is a consistency in the average output (dose rate) obtained by the actual dosimetry values and the expected output values obtained using decay method. The values obtained by actual dosimetry are within ±2% of the expected values.

Conclusion: The results thus obtained in a year wise comparison of average output by actual dosimetry done regularly as a part of Quality Assurance of the Telecobalt Radiotherapy Unit and its deviation from the expected output data is within the permissible limits. Thus our study shows a trend towards uniformity and a better dose delivery.

Keywords: Dosimetry, Teletherapy, Output, Dose, Consistency, AAPM

List of abbreviations used:

SKIMS: Sher-I-Kashmir Institute of Medical Sciences
SSD: Source to Surface Distance
SAD: Source to Axis Distance
QA: Quality Assurance
ICRU: International Commission on Radiation Units and Measurement
AAPM: The American Association of Physicists in Medicine
IAEA: International Atomic Energy Agency
TRS-398: Technical Report Series No. 398
PDD: Percentage Depth Dose
TAR: Tissue Air Ratio

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Introduction

Cobalt, a chemical element with symbol Co and atomic number 27, is found naturally only in chemically combined form. Cobalt-59 is the only stable cobalt isotope. Twenty two radioisotopes have been characterized with the most stable being Cobalt-60 with a half-life of 5.2714 years.[1] Cobalt-60 is a synthetic radioactive isotope of cobalt. Due to its short half life it is not found in nature. Cobalt-60 (Co-60 or ^{60}Co) is used as a gamma ray source as it can be produced in predictable quantity and high activity by bombarding cobalt -59 with neutrons. Cobalt-60, decays to Nickel-60, ($^{60}Ni_{28}$) by the emission of beta particle. The activated nickel nucleus emits two gamma ray photons with energies of 1.17MeV and 1.33MeV [1, 2, 3] resulting in an average beam energy of 1.25MeV. The energy of these gamma rays is used in radiotherapy to treat conditions like cancer. As Co-60 decays, this decrease in activity requires periodic replacement of the sources used Telecobalt unit and is one of the reasons why cobalt machines have been partly replaced by linear accelerators in modern radiation therapy. [3] But Telecobalt machines are still in widespread use worldwide, since the machine is reliable and simple to maintain compared to modern linear accelerators.

In treating patients with radiation, the radiation oncologist prescribes a treatment regimen (including the radiation dose) whose goal is to cure or control the disease while minimizing complications to normal tissues. In general, published clinical and experimental results demonstrate that the response of tumors and normal tissues to radiation is highly variable. Moreover, for some tumors and normal tissues the dose response curves may be very steep in the therapeutic dose range, i.e., a small change in dose can result in a large change in clinical response. In addition, the prescribed radiation dose to the tumor is usually, by necessity, constrained by the tolerance dose of the surrounding normal tissues. Consequently, since the “window” for optimal treatment can be quite narrow, the radiation dose must be delivered accurately and consistently. Delivery of treatment in an accurate and consistent manner is by no means easy to achieve, since the radiation therapy process is a complex interweaving of a number of related tasks for designing and delivering radiation treatments. One among them is the accurate dose delivery which relays on accurate dosimetry of the source.

The International Commission on Radiation Units and Measurement [25] has recommended that the dose delivered should be within ±5% of the prescribed dose. Considering the many steps involved in delivering dose to a target volume in a patient, each step must be performed with accuracy much better than ±5% to achieve the: International Commission on Radiation Units and Measurement (ICRU) recommendation.

It is important to mention that quality of care must be an intended goal and exist in practice before procedures can be developed. “Quality assurance” is all those planned or systematic actions necessary to provide adequate confidence that the radiation oncology service will satisfy the given requirements for quality care. The American College of Radiology [12, 13, 14, 15, 16] has Standards for Radiation Oncology which specifies a QA program including patient chart review.[5, 6, 7, 8, 9, 10, 11, 18, 19, 26, 28, 29]

The tolerance values in this section (QA) for radiological, geometrical, and mechanical parameters, were applicable and adopted from, The American Association of Physicist in Medicine.[7] These values are intended to make it possible to achieve an overall dosimetric uncertainty of ±5%. These uncertainties are generally perceived as clinically acceptable and technically achievable. [25] The tolerances listed in those tables should be interpreted to mean that if a parameter either exceeds the tabulated value (e.g., the measured isocenter under gantry rotation exceeds 2 mm diameter) or that the change in the parameter exceeds the tabulated value (e.g., the output changes by more than 2%), then an action is required. [20, 22, 26]

Dosimetry is a measurement of dose rate of any radiation generating equipment and in radiotherapy, it centers an accurate dose delivery, and thus enhances the confidence for an accurate therapy. The Co-60 teletherapy unit under the trade name Theratron 780-E was commissioned in July 2001 at SKIMS. Our study is a part of QA done regularly for better treatment execution and radiation safety to both patients and radiation workers.

Materials and Methods:

The dosimetry over the period of ten years was performed using following equipments.

- Farmer 2570*
- Ionex 2500/3*
- Full scatter water phantom (30x30x20)
- Aneroid Barometer#
- 2581 Thimble Chamber (0.6cc)
- 2571 Thimble Chamber (0.6cc)
- Thermometer

*Electrometers (Farmer 2570 and Ionex 2500/3 used for dose measurements are timely calibrated from secondary standard dosimeters in BARC lab, along with thimble shaped Ion Chambers. [17]

#The Aneroid Barometer was also calibrated at the time of installation of Theratron E.

Method:

The methodology used consisted of:

1. Calibration of electrometers and thimble chambers with the national standard at Bhabha Atomic Research Centre (BARC). Then measurement of doses (output) for SSD and SAD techniques following: IAEA, TRS-398, (2000) protocols for absorbed dose determination in External Beam Radiotherapy (EBRT). [30] The calibrated thimble chamber is placed at reference depth of 10 cm in 30 x 30 x 20 cm^3 water phantom. For SSD measurements the surface of water is kept at 80 cm, such that source to chamber distance is 90 cm. Then five readings are taken each for 1 minute, for reference field size taken as 10 x 10 cm^2. For SAD measurements water surface is kept at 70 cm, so that source to chamber distance is 80 cm. Here again five readings are taken each for one minute for reference field size 10x10cm^2.
2. The Absorbed dose rate to water at reference depth is obtained by using the following formula:

Output (Dose rate in water) = $M_r \times K_{Pol} \times K_s \times K_Q \times N_{DW} \times K_{TP}$ (IAEA, TRS-398, (2000) protocol)

M_r = Electrometer Reading obtained.

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

$|M_+|$ = Meter reading at + V_1

$|M_-|$ = Meter reading at – V_2

K_S = Recombination correction,

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

K_Q =This is the correction factor for energy and for Co-60 is taken as 1.

N_{DW} = Absorbed dose to water calibration factor for given electrometer and thimble chamber.

K_{TP} = Temperature, Pressure correction factor, $(273.2+T)/(273.2+T_0) \times P_0/P$ where P_o and T_o are the reference values(generally 101.3 kPa and 20° C).

3. Since the chamber has been kept at reference depth of 10cm, the output obtained from the above equation would be at 10cm depth. In order to obtain the output at d_{max} as a function of field size the above formula is divided by depth dose (at 10 cm depth) for SSD and TAR (at 10 cm depth) for SAD.
4. The half life of Co-60 is 5.27 years so, it decays by 1.089% every month. By multiplying the dose by factor 0.989, the expected output for coming month is obtained.

Then comparing the output obtained by the two methods (actual dosimetry and decay method), the percentage error for every month and there after every year had been calculated.

Results and Discussion:

Table 1 and Table 2 show distribution of the actual output measured by the standard techniques and expected value for output calculated using the decay method for SSD and SAD respectively. The output of the Telecobalt unit at the time of source loading i.e. July 2001 was 2.8064 Gy/min for SSD and 2.7603 Gy/min for SAD and the output after one month using decay law was 2.7755 Gy/min for SSD and 2.7299 Gy/min for SAD for 10x10 cm^2 field size. Figure 1 and 2 represents graphically the extent of overlap of the two dose rates for SSD & SAD Techniques respectively.

It is clear from Table 1 and Table 2 that the percentage error obtained during each year for both SSD and SAD techniques varies between +1.3310% to -1.6568% This variation has been always less than ±2%, result which is consistent with the protocols [12, 7, 8, 9, 10, 18, 19, 21, 22, 24, 27, 28] prescribed. These values are intended to make it possible to achieve an overall dosimetric uncertainty of ±5%. These uncertainties are generally perceived as clinically acceptable and technically achievable. [25]

The consistency checks of various dosimeters used for output measurements of Telecobalt unit using Sr-90 check source is also shown in Table 3. It can be observed that the variation has been always within ±1.5%.

Year	Av. Actual Output (Gy/min) O_i	Av. Output using Decay Factor (Gy/min) E_i	% Error $(O_iE_i)/E_i\times100$
2001	2.7482	2.7303	+ 0.655
2002	2.4534	2.4730	- 0.7926
2003	2.1339	2.1656	- 1.4638
2004	1.8709	1.8964	- 1.34
2005	1.6473	1.6607	- 0.8069
2006	1.4431	1.4542	- 0.7633
2007	1.2524	1.2735	- 1.6568
2008	1.1048	1.1152	- 0.93
2009	0.9827	0.9766	- 0.5939
2010	0.8639	0.8552	- 1.0173

Table 1, showing actual output and expected output in Gy/min and the % Error between the two for SSD @ 80cm.

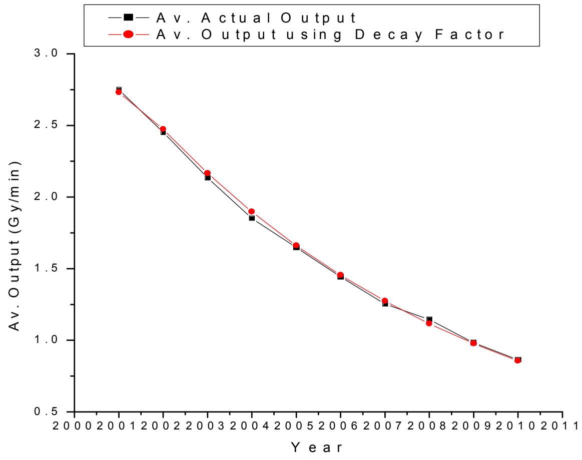

Fig. (1). Comparison between the actual and expected output (Gy/min), for SSD@80cm.

Year	Av. Actual Output (Gy/min) O_i	Av. Output using Decay Factor (Gy/min) E_i	% Error $(O_iE_i)/E_i \times 100$
2001	2.7053	2.6855	+ 0.737
2002	2.4203	2.4324	- 0.497
2003	2.1000	2.1300	- 1.408
2004	1.8551	1.8653	- 0.547
2005	1.6154	1.6334	- 1.102
2006	1.4125	1.4304	- 1.251
2007	1.2496	1.2526	- 0.239
2008	1.1115	1.0969	+ 1.331
2009	0.9643	0.9606	+ 0.385
2010	0.8458	0.8411	+ 0.559

Table 2, showing the Error of ± 3% between actual output and expected output in Gy/min for SAD Technique (SSD@ 70cm).

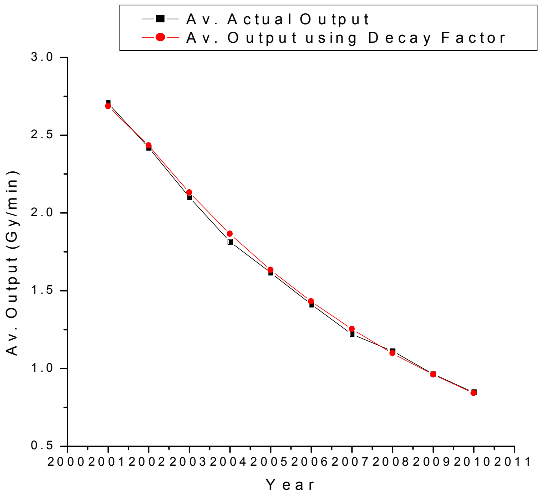

Fig. (2). Comparison between the actual and expected output (Gy/min), for SAD Technique (SSD@70cm).

Dosimeter	Values Obtained	Permissible
Ionex-2500/3	+1.48% to – 0.692%	± 1.5%
Farmer- 2570	+0.974% to – 1.5%	± 1.5%

Table 3: Consistency check of dosimeters for output measurement of Co-60.

Conclusion

The output obtained by using actual dosimetry over the period of 10 years i.e. 2001 to 2010, when compared to expected output, shows deviation within permissible limits i.e. ±2% annually. This reflects the consistency in measured output over the period of these 10 years and in turn shows the accuracy in dose calculation.

The study thus performed shows continuous trend towards uniformity and the review process has been effective in identifying the deficiencies and thus effective corrections, if any.

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