Proceedings of the Pakistan Academy of Sciences 50 (4): 309–314 (2013)
Copyright © Pakistan Academy of Sciences
ISSN: 0377 - 2969 (print), 2306 - 1448 (online)

Pakistan Academy of Sciences

Research Article

Verification of Absorbed Radiation Dose for X-rays through Lagrange's Interpolation Method

Saeed Ahmad Buzdar[1*], Qurat-ul-Ain Shamsi[1], M. Afzal[1], Aalia Nazir[1], Muhammad Altaf Hussain Nizamani[2] and Muhamad Asghar Gadhi[3]

[1]Department of Physics,
The Islamia University of Bahawalpur, Pakistan
[2]Department of Physics, University of Sind, Jamshoro, Hyderabad, Paksitan
[3]Bahawalpur Institute of Nuclear Medicine & Oncology (BINO), Bahawalpur, Pakistan

Abstract: The advent of modern technologies and mega voltage beam energies in radiation therapy has increased the demand of higher degree of accuracy and efficiency. We intended to increase the efficiency of the radiation therapy by applying mathematical and computational tools not only to verify the measured Percentage Depth Dose (PDD) data but also to aid in rapid machine commissioning. Lagrange's interpolation method was used to calculate the absorbed doses at depths with step size of 1 cm. The measured PDD data at selected depths with 5 to 8 cm separation have been used as the points of interpolations. The interpolated results precisely agree with the measured data, and can be used as the input data for treatment planning. This exploration should be extended for the interpolation of dose for different field sizes as well so that the commissioning time can be further decreased and the reliability of the measured data is assured.

Keywords: Radiotherapy, treatment planning, percentage depth dose, commissioning

1. INTRODUCTION

Radiotherapy is the most widely adopted treatment technique for cancer. Radiation therapy is considered as a progressive field with an unexhausting struggle made by many radiation workers to enhance efficiency while maintaining a minimum compromise on accuracy. Becquerel and Rontgen are the one who have rolled the ball in the field of radiation therapy by discovering X-rays and gamma rays. As these radiations have the tendency to cut down the growth of oncocytes, treatment units like Cobalt-60 units and linear accelerators have been designed to target radiation beams on the region of interest [1]. Besides radiation treatment, surgery and chemotherapy are also preferred for treating tumors and it seems that the rates of tumor cure increases directly with increasing treatment options [2]. The field of radiation treatment progresses from the radiotherapy plans relied on orthogonal radiographs in which structures of interest were highlighted by large margins to more advanced imaging methods and planning softwares that provided the likelihood of more conformed radiotherapy and then further moved to Intensity Modulated Radiation Therapy (IMRT) [3].

Radiation treatment can either be external beam or internal beam therapy (brachytherapy). Treatment units like Cobalt-60 and LINACs are constructed to perform external beam therapy. In spite of the reduced maintenance and cost effectiveness of cobalt units, LINACs are the preferred the options for radiotherapy due to

---

Received, June 2012; Accepted, October 2013

*Corresponding Author: Saeed Ahmad Buzdar; Email: saeed.buzdar@iub.edu.pk

their incomparable versatility and working in dual beam modalities (electron beam or photon beam). Megavoltage photon beams from LINACs own the skin-sparing effect by sending radiation beams deeper in the body to treat deep residing tumors [4, 5].

Prior to make clinical use of treatment units, they have to undergo testing and commissioning by concerned persons. Owing to the perils caused by the radiations, commissioning must be performed steadily and with extreme level of precautions. This includes the generation of dose data by measuring percent depth doses in water phantoms which are selected by the dosimetry protocols as a reference material [6]. The processing and checking of beam data is as important as its generation before sending to the planning software which is responsible for calculating patient doses. Accurate beam data is very indispensible to form a model of dose calculation [7]. When standards for the generation of radiotherapy plans and its delivery are satisfied, treatment units can then be sent for treating actual patients [8]. This steady and methodical process normally requires a period of 6-7 months. In order to make the treatment plan more efficient, we have used Lagrange's Interpolation Method [9] to calculate percentage depth doses at various depths in a limited time span of 3-4 weeks.

2. METHODS FOR ABSORBED DOSE CALCULATION

Determination of dosimetric data is one of the most significant steps which must be taken during commissioning of the newly installed treatment units. This dose data is produced by calculating percentage depth dose (PDD) at increasing depths and for a number of field sizes in dummy patients, which may require a long time period. In order to shorten the time of commissioning, method of Lagrange's Interpolation has been used in this exploration for the calculation of percentage depth doses at various depths and its required expression is given below.

$$P_n(x) = y_0 \frac{(x - x_1)\,(x - x_2)....(x - x_n\ )}{(x_0 - x_1)\,(x - x_1)....(x - x_{n-1}\ )}$$

$$+ y_1 \frac{(x - x_0)(x - x_2)....(x - x_n\ )}{(x_1 - x_0)(x_1 - x_2)....(x_1 - x_n\ )} + \dots\dots\dots$$

$$+ y_n \frac{(x - x_0)(x - x_1)....(x - x_{n-1}\ )}{(x_n - x_0)(x_n - x_2)....(x_n - x_{n-1}\ )}$$

In this practice, percentage depth dose can be calculated for discrete depths and field sizes, with some reasonable step size, the rest of data can be interpolated to make that date continuous. Different interpolation techniques are available, but Lagrange's interpolation method [9] was opted in this attempt, for having a better accuracy, and its algorithm is convenient to be transformed in any object oriented programming language like JAVA, C++ or other. The dose in water or other patient equivalent phantoms are measured only for few discrete depths and field sizes, and the remaining data can be calculated using this method. $P_n(x)$ will generate the required point dose, for the particular depth x, where x_0, x_1, ., x_n are the known discrete depths and y_0, y_1, … , y_n are the known dose values.

3. RESULTS

The results are obtained by calculating percentage depth doses (PDDs), comparing the calculated data with standard data [10] and differences in percentage are then observed. The PDD data is calculated for both 6MV & 15MV X-rays. The measured dose data is chosen at some suitable separation to work as the points of interpolation while the remaining data is calculated through the help of Lagrange's interpolation method to form a continuous dose data.

The results for 6MV X-rays at an SSD of 100 cm are presented in Table 1. Measured dose data is selected at depths with 5 cm separation and the other data is calculated through lagrangian method of interpolation for various field sizes to ensure the continuity of dose data. The depth varies from 1.5 cm to 25 cm with the step size of 1 cm. the maximum difference went to 1.05%. The differences observed are very close to the accuracy and do not cross the accuracy limit which is considered to be reasonable if less than 2%. Some of the differences are so less that they can be regarded as touching the accurate value. Even no difference is seen at 17cm depth for 40 x40-cm field size.

Table 1. Percentage difference between measured & calculated PDDs (6 MV).

Square Field Side (cm) →	**4**	**7**	**10**	**20**	**30**	**40**
Depth (cm)						
1.5	0	0	0	0	0	0
2	0.51	0.48	0.48	0.22	0.23	0.19
3	0.61	0.53	0.4	0.32	0.13	0.12
4	0.44	0.42	0.13	0.02	0.03	0.03
5	0	0	0	0	0	0
6	0.11	0.16	0.08	0.11	0.05	0.07
7	0.11	0.14	0.09	0.01	0.01	0.11
8	0.15	0.12	0.07	0.1	0.03	0.09
9	0.06	0.16	0.07	0.05	0.12	0.11
10	0	0	0	0	0	0
11	0.02	0.05	0.02	0.03	0.01	0.03
12	0.04	0.09	0.02	0.05	0.15	0.06
13	0.04	0.14	1.05	0.18	0.13	0.09
14	0.08	0.06	0.07	0.05	0.1	0.03
15	0	0	0	0	0	0
16	0.27	0.17	0.18	0.15	0.07	0.11
17	0.46	0.02	0.24	0.12	0.04	0
18	0.49	0.12	0.32	0.08	0.01	0.06
19	0.24	0.08	0.14	0.07	0.02	0.06
20	0	0	0	0	0	0
21	0.28	0.34	0.19	0.1	0.07	0.09
22	0.56	0.36	0.34	0.2	0.17	0.21
23	0.66	0.54	0.42	0.03	0.28	0.27
24	0.81	0.51	0.57	0.06	0.35	0.26
25	0	0	0	0	0	0

The measured and interpolated results for 15 MV X-rays are presented in Table 2 which were obtained under the similar conditions as for 6 MV X-rays. The depth of maximum dose (d_{max}) lies deeper (2.9 cm) for 15 MV beam as compared to that for 6 MV. All of the differences are much less than 2%. The maximum difference emerges so far is of 1.44% while some differences are so less like 0.06% that they closely approach to the accurate value.

Table 2. Percentage difference between measured & calculated PDDs (15 MV) .

Square Field Side (cm) →	**4**	**7**	**10**	**20**	**30**	**40**
Depth (cm)						
2.9	0	0	0	0	0	0
3	0.29	0.33	0.52	1.23	1.44	1.32
4	0.22	0.19	0.36	0.33	0.57	0.5
5	0	0	0	0	0	0
6	0.46	0.27	0.38	0.26	0.25	0.39
7	0.48	0.44	0.38	0.43	0.43	0.39
8	0.49	0.49	0.37	0.4	0.44	0.32
9	0.29	0.3	0.24	0.16	0.23	0.17
10	0	0	0	0	0	0
11	0.31	0.1	0.19	0.13	0.09	0.15
12	0.45	0.2	0.27	0.2	0.15	0.1
13	0.38	0.16	0.24	0.19	0.27	0.14
14	0.43	0.14	0.23	0.27	0.22	0.07
15	0	0	0	0	0	0
16	0.21	0.19	0.12	0.13	0.23	0.29
17	0.48	0.2	0.21	0.24	0.25	0.33
18	0.23	0.13	0.2	0.28	0.17	0.26
19	0.1	0.06	0.08	0.2	0.16	0.21
20	0	0	0	0	0	0
21	0.25	0.47	0.21	0.14	0.1	0.17
22	0.75	0.99	0.68	0.57	0.49	0.63
23	1.43	1.37	1.08	0.77	0.68	0.65
24	1.36	1.28	1.08	0.75	0.67	0.83
25	0	0	0	0	0	0

On attainment of very useful results, an attempt to further increase the efficiency was made, but increasing the distance gap for interpolation. All the exploration has been repeated for 8 cm distance separation (which was 5 cm previously). The difference remained within acceptable range, and it can offer to use a larger gap, at achieve more efficiency.

Fig. 1 shows the percentage differences graphically for 6 MV X-rays at various depths and field sizes. All the conditions for calculating doses are kept similar except the separation between the depths, at which measured data is selected, is extended to 8 cm with the intent to further enhance the efficiency of treatment plans. The larger peak is close to close 1.2% just beyond the depth of maximum dose. Fig. 2 is the graphical representation of the results for 15 MV X-rays for 10 x10-cm field size following same conditions at increasing depth

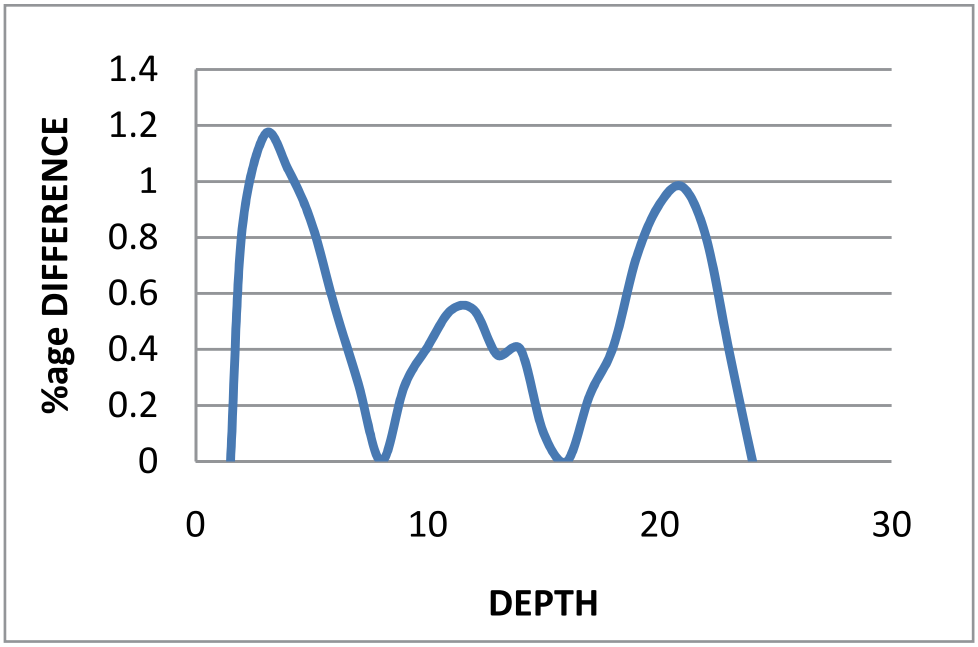

Fig. 1. Percentage difference between measured and interpolated Dose for 10 x 10 –cm field size, 6 MV X-ray.

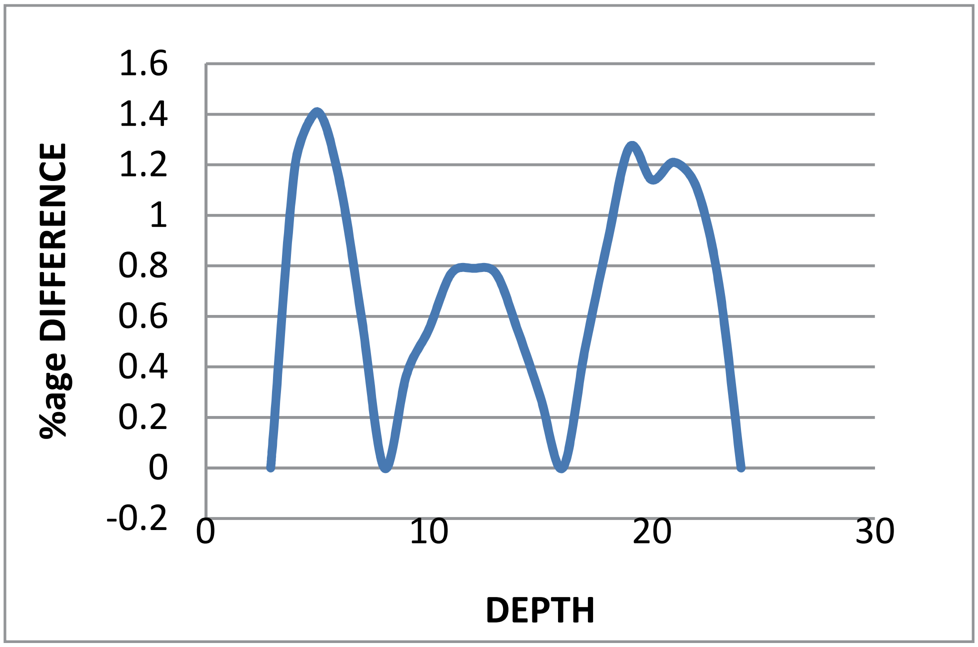

Fig. 2. Percentage difference between measured and interpolated Dose for 10 x 10 –cm field size, 15 MV X-ray.

from dmax to the depth of 25 cm. Larger peak is found a bit away from 1.4% but firmly fulfilling the needs of accuracy.

4. DISCUSSION

Percentage depth dose is a function to establish the variation of central axis depth dose which is a crucial step in the system of dosimetric calculations [13]. This step generates a depth dose data produced to foresee the distribution of doses in real cancer patients [14]. For this purpose, mathematical tools like Lagrange's interpolation method were employed to calculate PDDs with the desired accuracy and efficiency in making radiotherapy plan.

From the results obtained for both 6MV and 15MV X-rays, it is visualized that the d_{max} of 6MV energies was not as deep as that of 15MV. This is due to the reason that 15MV energy beam is more energetic than the beam of 6MV energy and hence deposits a maximum dose at larger depths. It is clear from the results that the calculated PDD do not differ largely from the standard PDD data for both energy beams at depths with 5 cm separation. This separation has provided a reliable dose data indeed. For the sake of enhancement of efficiency of radiotherapy plans while paying full concentration to the accuracy of dose data, it is seen in graphically shown data that the extended depth of 8 cm has also become successful in providing a reliable dose data. Although the differences observed for extended separation are slightly greater than that for reduced separation yet they strongly fulfills the demands of accuracy and considered as an almost accurate depth dose data.

5. CONCLUSIONS

These investigations focused on increasing efficiency of radiotherapy treatment practices. The suggested numerical approach can reasonably benefit the radiation dosimetrists / medical physicists, not only in a quick commissioning process but also within the accuracy tolerance. It is recommended to measure dosimetric parameters like percentage depth dose, Tissue Air Ratio, Tissue Maximum Ratio etc. on different steps of depth and field size to obtain a discrete set of data. The Lagrange's interpolation method can be used to fill the data set to make it continuous. The interpolated results precisely agree with the measured data, and can be used as the input data for treatment planning. This exploration should be extended for the interpolation of other dosimetric quantities as well so that the commissioning time can be further decreased and the reliability of the measured data is assured.

6. REFERENCES

1. Kardamakis, D., E. Gustavson-Kadaka, E. Spiliopoulou & S. Nilsson. The history of Radiumhemmet in Stockholm in the period 1895-1950: The transformation of an outpatient clinic to an academic department. *Vesalius* 16 (2): 95-99 (2010).
2. Vlachopoulou, V., G. Malatara, H. Delis, K. Theodorou, D. Kardamakis & G. Panayiotakis. Peripheral dose measurement in high-energy photon radiotherapy with the implementation of MOSFET. *World Journal of Radiology* 2 (11): 434-439 (2010).
3. Bhide, S.A. & C.M. Nutting. Recent advances in Radiotherapy. *BMC Medicine* 8: 25; 1-5 (2010).
4. Sixel, K.E., & E. Podgorsak. Buildup region and depth of dose maximum of mega voltage X-ray beams. *Medical Physics* 21:411-416 (1994).
5. Yadav G, R.S. Yadav & A Kumar. Effect of various physical parameters on surface and build-up dose for 15-MV X-rays. *Journal of Medical Physics* 35:202-206 (2010).
6. Fujita Y, N Tohyama, A. Myojoyama & H. Saitoh. Depth scaling of solid phantom for intensity modulated radiotherapy beams. *Journal of.Radiation Research* 51(6):707-713.(2010).
7. Chen, L. L.X. Chen, H.Q. Sun , S.M. Huang, W.Z. Sun, X.W. Gao & X.W. Deng. Measurement and comparisons for data of small beams of linear accelerators. *Ai Zheng (Chinese Journal of Cancer)* 3:328-332 (2009).
8. Sen, A. & M.K.. West. Commoissionig experince and quality assurance of helical tomotherapy machine. *Journal of Medical Physics* 34(4):194-199. (2009).
9. Patil, P.B, & U.P. Verma, Numerical Computational Methods. *Narosa Publishing House,* (2006).
10. Jordan T.J. Megavoltage X-RAY beams: 2-50 MV. *British Journal of Radiology Supplement* 25: 62-109 (1996).
11. Mohan R., K. Jayesh , R.C. Joshi, M. Al-Idrisi, P. Narayanamurthy & S.K. Majumdar. Dosimetric evaluation of 120-leaf multileaf collimator in a Varian linear accelerator with 6-MV and 18-MV photon beams. *Journal of Medical Physics* 33(3):114-118

(2008).

12. Podgorsak, E.B. Radiation oncology Physics: A hand book for teachers and students. International Atomic Energy Agency, Vienna (2005).
13. Khan, F.M. *The Physics of Radiation Therapy*. Lippincott, Williams and Wilkins, Baltimore, MD, USA (2003).
14. Buzdar, Saeed Ahmad. *Optimization of Accuracy Concepts in Treatment Planning for Conformal Radiotherapy.* PhD Thesis, The Islamia University, Bahawalpur (2008).