The Chittagong Univ. J. Sci. 40 : 47-58, 2018

Comparative Studies of Dose Measurements in Cornea and Mantle Shielding Block for High Energy Gamma Radiation (^{60}Co) in Radiotherapy Treatment

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Abstract

Cornea and Mantle shielding blocks were used to evaluate the dosimetry features of blocked beam radiotherapy. These blocks were used to produce the blocked beams for 5×5 cm^2 and 30×30 cm^2 field sizes. Doses were measured and calculated by the Clarkson's method and compared mutually. The variations of 0.05%, 0.92% and 0.99% were observed at three dose investigation points of 5×5 cm^2 field size for cornea block. For mantle block the variation between measured and calculated values were found to be 1.97%, 2.46%, 2.39%, 2.13%, 2.00% and 1.93% at six dose investigation points of 30×30 cm^2 field size. In this study dose calculated by the empirical relation using correction factors $C^{i}_{j\times k}$ and CF_i were found approximately equal to the experimental value. In the cases of both cornea and mantle shielding the calculated mean value of uncertainty in dose measurement between calculated dose values of Clarkson’s method and empirical relation was found satisfactorily to be within ±5.0%, fulfilling to the International Commission on Radiation Units and Measurements (ICRU) [1].

Keywords: *Dose; Mantle block; Cornea block; Clarkson's method; Radiotherapy*.

প্রতিরোধী রশ্মিগুচ্ছ চিকিৎসায় দাগ পরিমাপক বৈশিষ্ট্যসমূহ মূল্যায়নের জন্য কর্ণিয়া ও আবরণী বর্মায়ন চৌকোণ খণ্ডসমূহ ব্যবহার করা হয়েছে। এ চৌকোণ খণ্ডসমূহ ৫ × ৫ সে.মি.^{২} এবং ৩০ × ৩০ সে.মি.^{২} আকারের প্রতিরোধী রশ্মিগুচ্ছ ক্ষেত্র তৈরীতে ব্যবহৃত হয়েছে। দাগসমূহ পরিমাপ করা হয়েছে ও ক্লার্কসনের পদ্ধতিতে হিসেব করা হয়েছে এবং পারস্পরিক তুলনা করা হয়েছে। কর্ণিয়া চৌকোণ খণ্ডসমূহের জন্য ৫ × ৫ সে.মি.^{২} আকারের রশ্মিগুচ্ছ ক্ষেত্রের তিনটি অন্বেষণ বিন্দুতে ০.০৫%, ০.৯২% এবং ০.৯৯% ভিন্নতার মাত্রা অবলোকন করা গিয়েছে। আবরণী চৌকোণ খণ্ডসমূহের জন্য ছয়টি অন্বেষণ বিন্দুতে পরিমাপকৃত ও হিসেবকৃত মানের মধ্যে ভিন্নতার মাত্রা যথাক্রমে ১.৯৭%, ২.৪৬%, ২.৩৯%, ২.১৩%, ২.০০% ও ১.৯৩% পাওয়া গিয়েছে। এ গবেষণায় $C^{i}_{j\times k}$ এবং CF_{i} সংশোধনী উপাদান সম্বলিত প্রায়োগিক সম্পর্ক ব্যবহার করে হিসেবকৃত দাগসমূহ পরীক্ষালব্ধ মানসমূহের প্রায় সমান পাওয়া গিয়েছে। কর্ণিয়া ও আবরণী উভয় বর্মায়নে ক্লার্কসনের পদ্ধতিতে এবং প্রায়োগিক সম্পর্ক ব্যবহার করে হিসেবকৃত দাগ পরিমাপের অনিশ্চয়তা সন্তোষজনক ভাবে আন্তর্জাতিক বিকিরণ একক ও পরিমাপ কমিশন (ICRU) অনুসারে ±৫.০% এর মধ্যে পাওয়া গিয়েছে।

1. Introduction

The principle of application of radiotherapy technique for the treatment of malignant diseases is to deliver a dose as high as possible to malignant tumor cells with minimum detriment to surrounding healthy tissues. From the view point of radiation protection on the basis of "As Low As Reasonably Achievable (ALARA)" concept, one of the basic principles of using ionizing radiation in medical fields is that the dose to surrounding tissues should be minimized by using the best available techniques, and to take measures to reduce the doses as far as possible to other parts of the body as well as organs at risk [2]. In addition, dose uniformity within the tumor volume and sparing of risk organs are important considerations in judging a treatment plan. Shielding of vital organs within a radiation field is one of the major concerns of radiotherapy. To optimize radiation protection during the radiotherapy treatment, it is necessary to minimize radiation exposure to the healthy tissue [3]. Shielding blocks play an important role for minimizing unnecessary exposure in clinical application of radiotherapy [4]. The target or treatment volume is often irregular in shapes in contrary to the square or rectangular fields employed in standard dose distribution data collection [5]. Modification of beam affects the dose received at the target point. Dose measurement for any field other than rectangular, square or circular field may be time consuming. The calculation of dose in irregular fields with Clarkson's method is also time-consuming. Therefore, several approaches are in progress for making generally applicable methods for calculation of doses in individual irregular fields. The overall objectives of the present study cover dose calculation and investigation procedures in irregular fields to avoid undesirable radiation hazard and ensure quality assurance (QA) for the accuracy in radiotherapy treatment planning.

2. Materials and Methods

2.1 Investigation of Beam Profile for Reference Data

Doses were measured in open field of size 5×5 cm^2 and 30×30 cm^2 at depth 0.5 cm and source to detector surface distance of 80 cm across the X-axis of Phantom surface to check the beam profile and thereby establishing the dose symmetry and uniformity. The field sizes and dimensions of the solid phantom were constructed

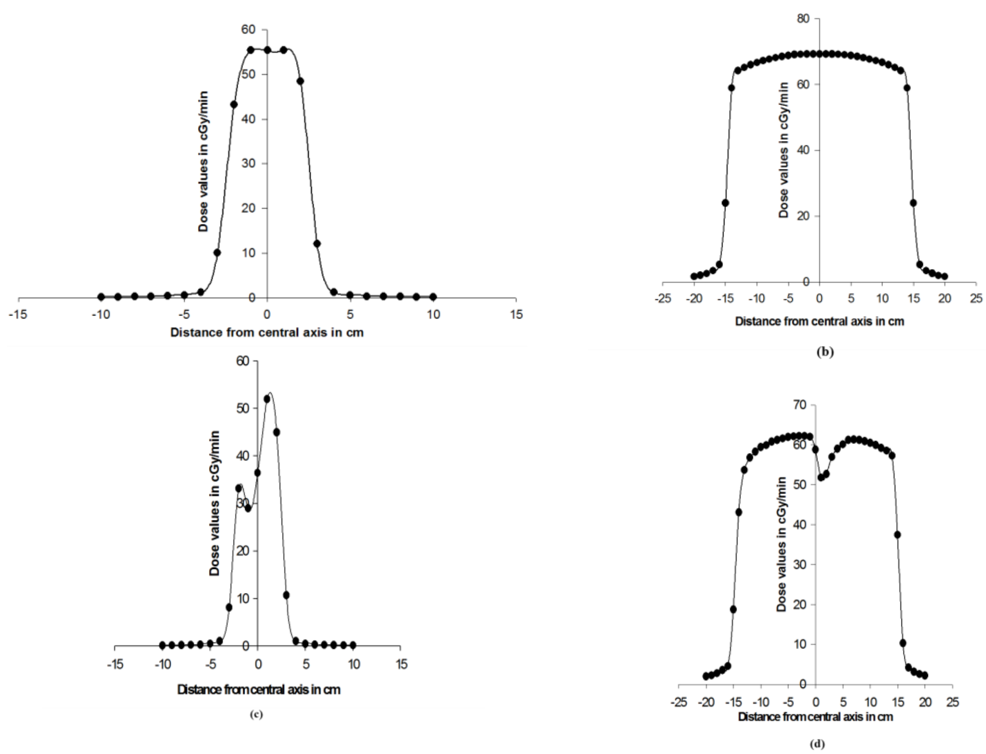

Fig. 1: Graphical presentation of open beam profile data (a & b), and blocked beam profile data (c & d).

ensuring a margin of 10 cm in all sides having a margin of 5.0 cm beyond the dose measurement point. The doses were measured at 1.0 cm increments from centre of the field to either edges extending 5 cm beyond the specified field sizes with a view to observe the penumbra regions on each axis. The dose at the centre of the field is termed as the central axis dose and doses in other points were expressed as percentage to this central axis dose. The graphical presentations of beam profile data of open and blocked beams are shown in Figures 1(a, b) and 1(c, d) respectively. The open field dosimetric scan-data were being preserved and considered as reference data during dosimetry for all irregular fields.

2.2 Dose Investigation for Photon Beam of ^{60}Co Unit

Photon beam doses were investigated in irregular shaped fields of Cornea and Mantle shielding blocks with a tissue equivalent solid phantom in slab form of dimension 40 cm × 40 cm × 10 cm. Routine therapy application procedures which were traceable to international norms for radiotherapy practices were followed during dose determination in solid phantoms for ^{60}Co teletherapy unit. Doses were investigated at different interested points with 0.6 cc Farmer type ionization chamber [6] at 0.5 cm depth of the phantom integrated with PTW UNIDOS dosimeter [6]. The different points of dose investigation along the X-axis of phantom surface are designated by the arabic numerals as 1, 2, 3, 4, 5, 6...etc. During dose investigation, the fields were modified in accordance with the simulated irregular fields using beam modifying blocks and under these conditions doses were measured at different interested points. Beam modifying blocks were then removed very carefully to make the fields open and doses were investigated in those points to see, if there was any difference between the two measurements with open and modified fields. To calculate dose at any point using Clarkson's method, the field around that point were divided into several sectors of angle 10^0 [4], and doses at each of sectors were calculated. Along with this, doses of blocked beams were also calculated by our proposed empirical relation given below where the determined values of two correction factors, C^i_{jxk} and CF_i were used.

$$D_{W,E_{corrected(Emp.)}} = (OFD) \times C^i_{j \times k} \times CF_i \times K_{TP} \tag{1}$$

Here *OFD* is the Open field dose and

K_{TP} represents Temperature–Pressure correction factor.

The correction factors $C^i_{j \times k}$ and CF_i were determined for the respective dose investigation points. The accuracy of the empirical method was verified experimentally by measuring the dose in solid phantom and was found to be satisfactory within ± 5% [1].

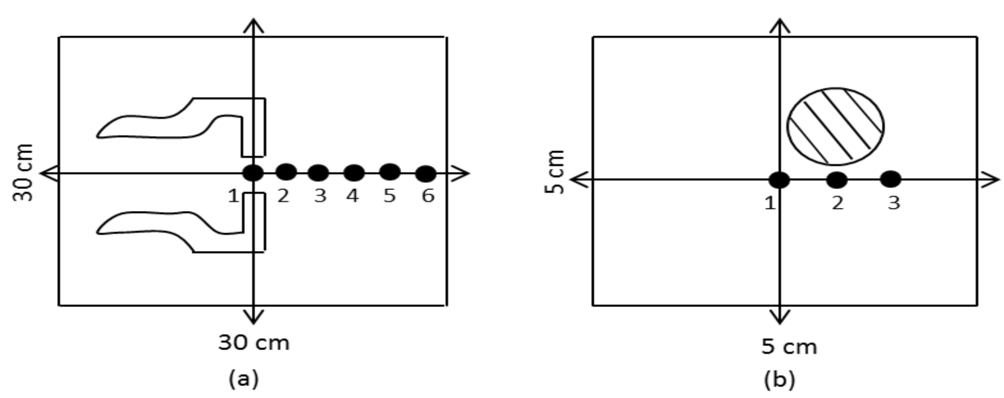

Fig. 2 (a & b): Points of dose calculation both in Clarkson’s method and empirical relation for mantle and cornea shielding.

3. Results and Discussion

Doses measured and calculated by the Clarkson's method were compared and variation of 0.05%, 0.92% and 0.99% was observed at points 1, 2 and 3 for Cornea block of field size 5 × 5 cm^2. The measured dose of blocked beam using Cornea shielding and calculated by the above procedure using Clarkson's method is compared and maximum variation of 0.99% and minimum variation of 0.05% was observed. In case of Cornea shielding the maximum and minimum %-difference of dose between the Clarkson calculation and that from the empirical relation were found to be 0.99% and 0.05%, respectively. The dose calculated by empirical relation using the values of the correction factors $C^{i}_{j\times k}$ and CF_i in cornea block was approximately equal to the measured dose of blocked beam. The calculated values of $C^{i}_{j\times k}$ and CF_i are presented in Table 1. In cornea shielding the %-difference between blocked and open beam of field size 5×5 cm^2 were 34.28%, 6.26% and 4.33%. The maximum reduction of dose is found at point-1 which is 1 cm apart from the central axis depth dose point. The correction factors C^{i}_{jxk} and CF_i at these points are 0.6960 and 1.0001 respectively. Doses measured and calculated by the Clarkson method are compared and their variation of 1.97%, 2.46%, 2.39%, 2.13%, 2.00% and 1.93% were observed at the investigation points 1, 2, 3, 4, 5, 6 for Mantle block of field size 30 × 30 cm^2. The measured dose of blocked beam using Mantle block was compared with that calculated by the Clarkson method. The maximum and minimum variations of 2.46% and 1.93%, respectively, were observed. In case of Mantle block, the maximum and minimum difference of doses between the Clarkson value and that from the empirical relation were found to be 2.46% and 1.93%. The dose calculated by empirical relation using correction factors C^{i}_{jxk} and CF_i was found approximately equal to the corresponding measured dose of blocked beam. In mantle shielding the difference between blocked and open beam were 9.19%, 19.96%, 18.59%, 11.96%, 8.57% and 6.56% at the six different points mentioned earlier.

The maximum reduction of dose with Mantle shielding was found at the second dose measurement point which was 2 cm far from the central axis depth dose point. The correction factors C^{i}_{jxk} and CF_i at these points were 0.9298 and 0.9754, respectively.

Table 1**:** Correction factors of empirical relation for cornea and mantle shielding.

	Dose investigation points	Correction factor $C^{i}_{j\times k}$	Correction factor CF_i
Cornea Shielding	1	0.6960	1.0006
	2	0.9842	1.0093
	3	0.9733	1.0101
Mantle Shielding	1	1.0502	0.9803
	2	0.9298	0.9754
	3	0.9451	0.9760
	4	1.0192	0.9788
	5	1.0571	0.9799
	6	1.0797	0.9807

The comparison among the doses in blocked beam, open beam, Clarkson's method and empirical relation is shown in Figures 3 (a, b). It was found that dose calculated by Clarkson's method was little higher than the measured value both in cornea and mantle shielding. Dose measurement accuracy of Clarkson's method and experimental value was investigated by the newly developed empirical relation with the help of correction factors $C^{i}_{j\times k}$ and CF_i. In this study it was found that the accuracy between calculated dose using empirical relation and measured dose is satisfactory. This relation is more convenient than Clarkson's method.

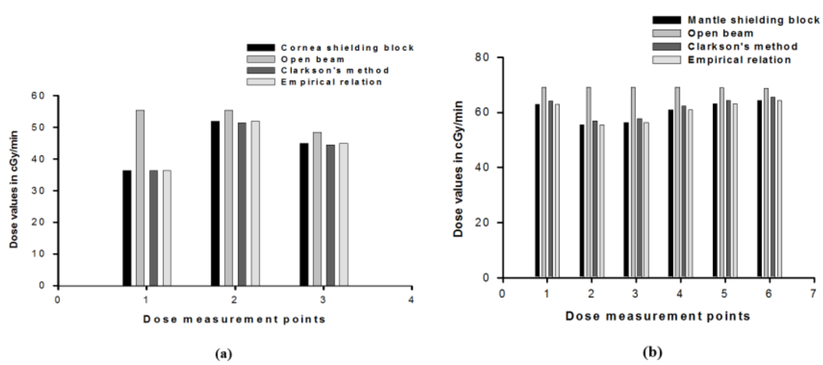

Fig. 3: Comparison among the doses in blocked beam, open beam, Clarkson's method and empirical relation in (a) Cornea and (b) Mantle shielding block.

The mean percentage difference with 1σ (standard deviation) between directly measured dose values at different points in irregular (blocked) fields and open fields was estimated. This percentage difference of dose values in irregular (blocked) fields of Cornea and Mantle blocks with in the corresponding dose values at the same points in open fields for ^{60}Co were 15.93% ± 12.98 (range 6.257% – 34.280%) and 12.47% ± 5.07% (range 6.56% – 19.96%) respectively. The average value of these mean differences with 1σ was 14.20 ± 1.73. The mean differences with 1σ between directly measured dose values in irregular fields and calculated dose values at the corresponding fields by Clarkson's method were 0.658% ± 0.427 (range 0.055% – 0.998%) and 2.147% ± 0.207 (range 1.93% – 2.46%) respectively. The corresponding values between Clarkson's method and newly developed empirical relation were, 0.658% ± 0.427 (range 0.055% – 0.998%) and 2.147% ± 0.207 (range 1.93% – 2.46%) respectively. The corresponding uncertainties were ± 0.649% and ± 0.096% respectively. The average values of these mean values (direct method and Clarkson's method, and Clarkson's method and empirical relation) were found to be 1.4025% ± 0.75 (range 0.658% – 2.147%) and 1.4025% ± 0.75 (range 0.658% – 2.147%) for ^{60}Co unit. The coefficients of correlation between the directly measured dose values in irregular fields and the calculated (Clarkson's method) dose values in the corresponding fields of Cornea & Mantle block for ^{60}Co were- 0.999 and 0.999. The mean value of these coefficients of correlation was 0.999. This means that the directly measured dose values were in good agreement with both Clarkson's method (0.999) and newly developed empirical relation (0.999) for ^{60}Co unit. The calculated mean values of uncertainty in dose measurement at the points of dose investigation with Cornea and Mantle shielding block between calculated dose values from Clarkson's method and the empirical relation were ±0.33% and ±1.08% respectively, which are statistically satisfactory, because according to the International Commission on Radiation Units and measurements (ICRU) the dose delivered to the target volume should be at least within ± 5% [1]. If the uncertainty of the dose delivered to the localized tumor is above 5% of that required, a more complicated symptom may arise within the body of the patient. Additionally, healthy cells in the vicinity of the tumor may be affected due to over exposure. On the other hand, an under dose of the required one may not cure the patient satisfactory. It is reported that high standard of accuracy is needed [7-11] in radiotherapy. Therefore, the overall uncertainties in radiation dosimetry be minimized and that accuracy be improved in the determination of absorbed dose from the radiation beams used in the Cancer therapy.

4. Conclusions

The present study provides quantitative information about dose reduction in irregular (blocked) fields in comparison to the open fields of corresponding size. The maximum dose reduction of approximately 34% for cornea shielding and 19% for mantle shielding block were respectively observed at two particular points for a ^{60}Co unit. This observation indicates that to achieve desired accuracy in conventional radiotherapy treatment for cancer patients with irregular fields, the extent of reduced dose in such irregular fields needs to be compensated. In this regard, the newly developed empirical relation could be a useful tool to rapidly assess the extent of dose reduction at a point of interest in the blocked fields. The directly measured dose values in irregular fields are found in good agreement with calculated dose values by empirical relation. Thus, the calculated dose values of empirical relation could be approximated equal to the experimentally estimated dose of irregular fields with reasonable accuracy. In this perspective, the empirical relation with appropriate correction factors of respective irregular fields could be convenient to get more required dosimetry data in the irregular fields.

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Manuscript received on 30 July, 2017, Revised manuscript received on 24 January, 2018 and accepted on 30 January, 2018