ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 5, Issue, 10, pp.2909-2912, October, 2013

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

MEASUREMENT OF HEAD SCATTER FACTOR FOR DIFFERENT TELECOBALT MACHINES USING MINI-PHANTOM

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ARTICLE INFO

Article History:
Received 22nd July, 2013
Received in revised form
27th August, 2013
Accepted 12th September 2013
Published online 10th October 2013

Key words:
Radiotherapy, Head scatter factor,
Mini-phantom, Collimator exchange effect

ABSTRACT

Telecobalt radiotherapy machines have become an integral part for treatment of cancer in developing countries. Head scatter factor (Sc) is very essential for beam modelling in treatment planning system for accurate dose delivery in radiotherapy. The magnitude of Sc depends on design and materials of source head of telecobalt machines. Mini-phantoms were fabricated indigenously using water equivalent material polymethyl methaacrylate (PMMA) for Sc measurement as per ESTRO recommendation. It is a simple and reliable tool for Sc measurements. The effect of variation of Sc values for change in field sizes, interchange of collimator jaws and introduction of wedges for three different telecobalt machines of same manufacturer were measured. The collimator exchange effect and the effect of wedges on Sc are within the acceptable limit. Our measurements indicate that the variation of Sc for different telecobalt machines has some uncertainty and for clinical usage Sc data should be measured for each telecobalt machines separately.

INTRODUCTION

Dose calculation at the dose specification point in a patient requires the value of output of the radiotherapy machine in water for a particular treatment condition. The output of the treatment machine for different field sizes varies with changes in the radiation scattered from the head of the treatment machine and changes in the radiation scattered from the irradiated part of the phantom to the reference point. The magnitude of these changes with field size can be taken into account in dose calculation by applying total correction factor (Sc,p). It is generally agreed that the total correction factor has to be separated into head scatter factor (Sc) and phantom scatter factor (Sp)[10]. It is essential to measure these components separately since the cobalt machines collimators and beam modifying devices modulate these two components differently [17]. Head scatter correction factor (Sc) is defined as the ratio of dose rate for a given field size to that of reference field size (10 cm x 10 cm) accounts for in-air variation of output with field size of megavoltage photon beams. All the beam shaping and beam modifying devices have great influence on Sc of the radiotherapy machines and for clinical use Sc should be measured for each and every telecobalt machines. The determination of Sc is earlier done by 'in-air' measurements with build up cap [18] thick enough to generate full dose build up at the depth of dose maximum (Dmax).But it is influenced by electron contamination and also dose maximum varies with increase in field size. In order to prevent the influence of electron contamination it has been recommended that head scatter measurements of radiotherapy machines are carried out using a mini-phantom rather than conventional build up cap. The comparison between these two methods for Sc measurements can be found in the literature [4, 7, 9]. In a publication from ESTRO booklet no: 6 [3] recommendations about using a mini-phantom for Sc measurements for high energy photon beams. Mini-phantom plays an important role for Sc measurement. The mini-phantom should resemble water (e.g. PMMA or Polystyrene). The shape of the mini-phantom may have a square or cylindrical cross-section perpendicular to its long axis. The depth of the mini-phantom should be 10 cm to prevent the electron contamination and diameter should be 4 cm to achieve lateral electronic equilibrium [5, 11, 15]. Hence Sc can be measured directly and accurately by using mini-phantoms. The magnitude of Sc mainly depends on the design and material used in the head of telecobalt machines, depth of measurement, interchange of collimator jaws and use of beam modifying devices. A number studies has been reported in the literature for characteristics of Sc on high energy X-ray beams [1, 2, 8, 19]. However only very few studies of Sc measurements using mini-phantom have been reported for telecobalt machines [13, 14]. In developing countries cobalt-60 radiotherapy machines still play a vital role in external radiotherapy management. In the present work we have locally fabricated low cost mini-phantoms of different shapes. We have measured the characteristics of Sc such as the effect of field sizes, collimator exchange effect (CEE), the effect of wedges using mini-phantom for three different cobalt-60 radiotherapy machines of same manufacturer and the results are reported. The measured data are very useful in day to day treatment planning and also useful for beam data modelling of treatment planning system to deliver the treatment accurately.

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MATERIALS AND METHODS

In this study three different telecobalt radiotherapy machines (Phoenix-147, Phoenix-148 and Phoenix-188) having average energy of 1.25 MeV were used. Sc values were measured using calibrated Farmer type ion chamber with electrometer CD-SSD-92(Control Dynamics, Bangalore, India). The chamber was tested for charge leakage and stem effect before its use.

Fabrication of different shapes of mini-phantoms

Two different shapes of mini-phantoms were fabricated as per ESTRO recommendations for Sc measurements which were made of water equivalent material polymethyl metha acrylate (PMMA). The chemical composition of PMMA is $(C_5O_2H_8)_n$ and it has a mass density of 1.16-1.20 gm/cc. The square mini-phantom has the dimensions of 25 cm length and 4 cm side and the cylindrical mini-phantom has the dimensions of 25 cm length and 4 cm diameter. Fig 1 shows the block diagram different shapes of locally fabricated mini-phantoms and the holder used for Sc measurements.

Where,
Sc(X, Y) denotes the head scatter factor for the collimator opening X and Y
E.g. 5 x 30 cm^2
Sc(Y, X) denotes the head scatter factor for the collimator opening Y and X
E.g. 30 x 5 cm^2

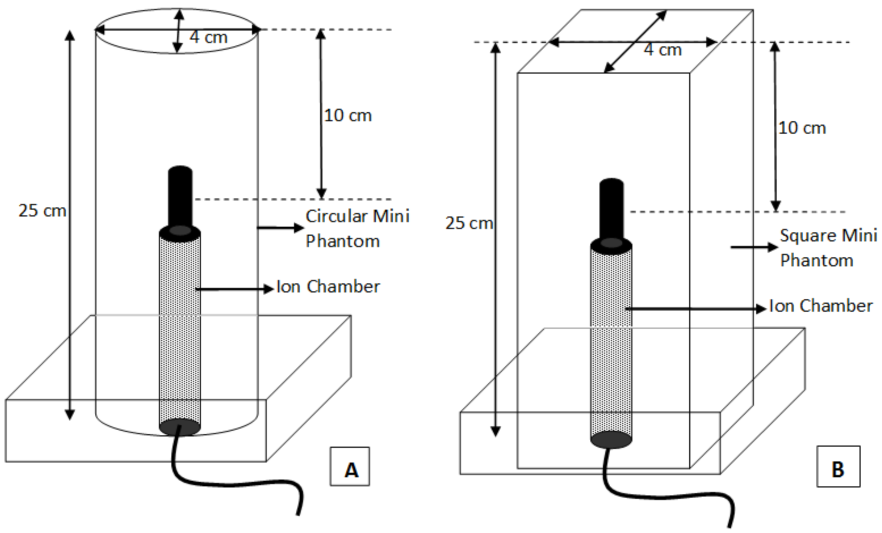

Fig 1. Block diagram of circular and square mini-phantoms

Experimental set up for Sc measurement

Fig 2 shows the experimental set up of mini-phantom for Sc measurements of different cobalt machines. The ion chamber is inserted into the mini-phantom and the long axis is aligned parallel to the central axis of the photon beam. The centre of the ion chamber active volume is exactly set at 80 cm source to chamber distance (SCD) which is the normal treatment distance for telecobalt machines. The measurement was performed for fixed treatment time setting of 1 minute. Both square fields and rectangular fields with lengths and widths varying from 5 cm to 30 cm were used uniformly in all the machines.

Fig 2. Mini-phantom experimental set-up for Sc measurement

Collimator exchange effect

For rectangular fields Sc for given collimator setting is different if the upper and lower collimator jaws are interchanged [16]. This effect is called collimator exchange effect and it depends on design of head of the telecobalt machine. The collimator exchange effect was calculated by measuring the head scatter factor for independent setting of X and Y collimator jaws for rectangular fields.

Collimator exchange effect = Sc(X, Y)/Sc(Y, X)

This effect was partially caused by the difference in scattered radiation that can reach the measurement chamber from same field size by interchanging upper and lower collimator jaw setting and partially by the difference in back scatter from upper and lower jaws to the measurement chamber. To study CEE, Sc was measured for independent setting of X and Y collimator jaws for rectangular fields which are commonly used in routine clinical applications.

Table 1. Comparison of Sc measurements for three Cobalt-60 machines of same manufacturer

S.No:	Field Size (cm^2)	Head Scatter Factor (S_C)		
		Phoenix -147	Phoenix -148	Phoenix -188
1	5 x 5	0.966	0.969	0.966
2	8 x 8	0.980	0.982	0.980
3	10 x 10	1.000	1.000	1.000
4	12 x 12	1.016	1.014	1.014
5	15 x 15	1.025	1.023	1.023
6	20 x 20	1.053	1.056	1.058
7	25 x 25	1.062	1.064	1.062
8	30 x 30	1.067	1.066	1.068

Effect of beam modifying wedges

Wedges are used in clinical practice to modify the dose distribution in the patient in the case of irregular body surface and tissue inhomogenities. They are made of high atomic number material and mounted below the collimator jaws. Physical wedges must be considered as an important additional source of scattered photons and the energy spectrum of primary beam will be modified [6,12]. To study the effect of wedges on Sc measurement 30°, 45° and 60° wedges were used for a range of field sizes.

RESULTS AND DISCUSSION

Fig 3 shows the values of Sc measured for Phoenix-147 telecobalt machine using both square and rectangular shaped mini-phantoms. From the graph it was found that the shape of mini-phantom has no influence in Sc measurement since the maximum percentage of deviation is only 0.3%. Measured values of Sc for square fields for all the three telecobalt machines of same manufacturer are shown in Table 1. From the measured data it was found that Sc values increases with

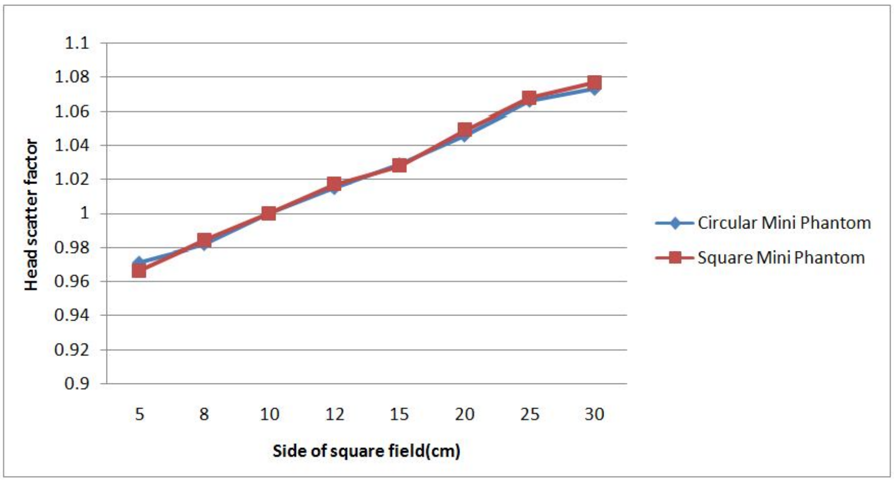

Fig 3. Comparison of different shape of mini-phantoms on Sc measurement

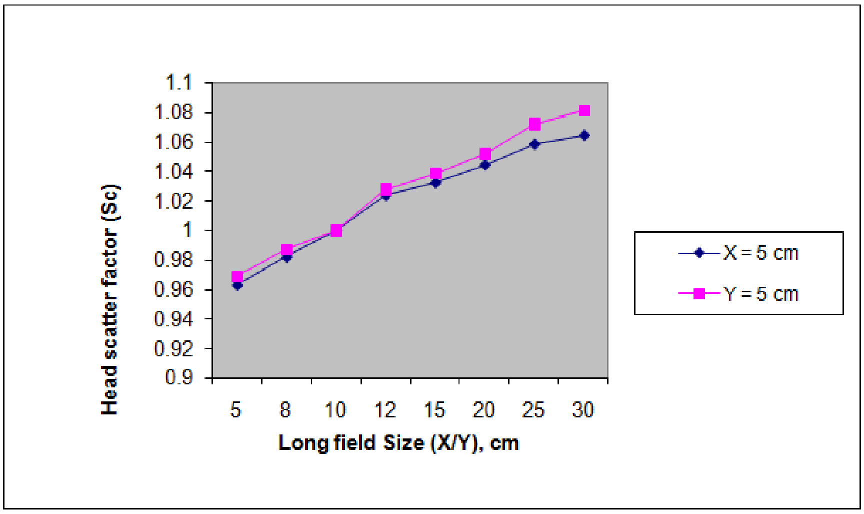

Fig 4. Collimator exchange effect Phoenix-147 Cobalt Unit

increase in field sizes due to more scatter photons reaching the detector. Sc values for all three Phoenix models are nearly equal and the maximum percentage difference between the values is less than ±1%. The effect of collimator exchange on Sc values were measured for Phoenix-147 using circular mini-phantom and recorded in Table 2. The maximum percentage of variation for Phoenix-147 machine is ±1.59% it is due to the distance between the source and the X and Y collimator parts of telecobalt machines. Figure 4 shows the effect of collimator exchange on Sc values and the CEE values always same for small fields and significant variation is observed in larger fields. Table 5 shows the measured values of Sc for open and wedges (30°, 45°, 60°) for various square fields of Phoenix-147 machine. From the measurement it is observed that the values of Sc for open and wedge fields are nearly same and this may be due to monoenergetic characteristics of gamma ray beams. Therefore Sc measured for open beam can be used for wedged beam also.

Table 2. Collimator Exchange Effect for Phoenix-147 Cobalt machine using Circular mini Phantom

S.No:	Long Field Size (X/Y)cm	Mini Phantom measurement(X,Y)		% Deviation
		X=5 cm	Y=5cm	
1	5	0.963	0.969	-0.623
2	8	0.982	0.987	-0.509
3	10	1.000	1.000	0.000
4	12	1.024	1.028	-0.391
5	15	1.032	1.039	-0.678
6	20	1.044	1.052	-0.766
7	25	1.058	1.072	-1.323
8	30	1.064	1.081	-1.598

Table 3. Comparison of Sc measurements for open and wedge fields for Phoenix-147 machine

Field Size (cm^2)	30° Wedge	45° Wedge	60° Wedge	Open field
5 x 5	0.964	0.963	0.961	0.966
8 x 8	0.979	0.977	0.974	0.980
10 x 10	1.000	1.000	1.000	1.000
12x 12	1.015	1.013	1.011	1.016
15x 15	1.023	1.022	1.021	1.025

Conclusion

Different shaped low cost mini-phantoms were fabricated for Sc measurement of three different telecoblt machines. Our results suggest that mini-phantom is a simple and reliable tool for Sc measurement accurately and the shape of the mini-phantom has no influence on Sc measurement. Our study indicates that Sc values varies with increase in field size and also varies with machine to machine, therefore for clinical use it should be measured for each machine separately. From the measurements it was observed that the effect of collimator exchange on Sc for telecobalt machines is relatively small. Our study also indicates that the effect of wedge filters on Sc values yields significant contribution and more for larger fields but Sc measured for open fields and wedge fields are nearly equal. Hence Sc values measured for open fields can be used for wedge fields also. Our measurements are in good agreement with Sc data measured using build up cap. From this study we conclude that Sc data can be measured using mini-phantom directly and accurately in telecobalt machines. For clinical usage Sc data should be measured for each and every telecobalt machines separately.

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