Iran. J. Radiat. Res., 2007; 5 (2): 91-95

Experimental evaluation of midline dose calculation methods in *In vivo* dosimetry using anatomic thorax phantom

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Background: *In vivo* dosimetry is a method for estimation of overall error in the delivered dose to the patients at the end of radiotherapy process. In this research, two methods for target dose calculation were evaluated on midline and central axis of photon beams in *in vivo* dosimetry of thorax fields. ***Materials and Methods:*** Entrance and exit doses for anterior and lateral fields of thorax were measured in thorax phantom using diode dosimeter. Also, the doses of some points on midline and central axis were measured in thorax phantom using ionization chamber. The dose at these points was calculated using entrance and exit doses by geometric and arithmetic mean methods. The calculated doses were compared with measured doses. ***Results:*** In all cases, arithmetic mean method showed errors from %8.8 to 19% for points on midline and central axis in comparison to measurements. The range of errors for geometric method was from %1.5 to %8 depending on distance from midline. ***Conclusion:*** The results showed that doses of points on midline and central axis can be calculated with acceptable accuracy from entrance and exit doses using geometric mean in thorax fields. **Iran. J. Radiat. Res., 2007; 5 (2): 91-95**

Keywords: *In vivo dosimetry, midline dose, radiotherapy of thorax, exit dose, entrance dose.*

INTRODUCTION

Accuracy in the delivered dose to the patients plays an important and vital role in radiotherapy treatments. This happens because of steep gradient of dose-local control and dose-normal tissue complication probability curves. Dosimetric uncertainty of 3%-4% (one standard deviation) in the delivered dose to the target volume as an acceptable level has been recommended[1-3]. In many centers, in vivo dosimetry using thermoluminance dosimeters (TLD) and diodes are used routinely to verify the actual delivered dose to the patients[1, 4, 5]. Recently, application of portal imaging devices as a tool for in vivo dosimetry has been evaluated[6-8].

In some radiotherapy centers entrance doses are measured and used for evaluation of source to patient distance (SSD), dose rate, and treatment time[9-11]. However, all errors in the delivered dose to the patients could not be revealed using entrance dose. So, in some occasions exit dose measurements are performed to provide the required data for delivered dose evaluations[5,9,10]. Exit dose measurements are useful for dose verification of dose calculation methods in treatment planning process. Finally, the combination of entrance and exit doses results could differentiate the origin of the observed errors in patient dosimetry.

It is desirable to compare the measured dose to the prescribed dose to the center of target volume. In order to estimate the dose received to the center of target volume, measured entrance and exit doses can be used[4,5,9,12]. There are a few methods for determination of dose at the dose specified point from the measured entrance and exit dose values[13-17]. Using these methods, the midline dose and the dose of points situated on the central axis could be determined from the entrance and exit doses, measured on the patients during treatment.

In our study the arithmetic and geometric mean methods for the midline dose

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determination were evaluated for thorax region in presence of lung inhomogeneities. Also, the feasibility of these methods in dose calculations for points on the central axis of beam was studied.

MATERIALS AND METHODS

Midline dose calculation methods

Before any description about midline dose calculation methods, we recall some used definitions in this study. The midline point is defined as the point on the rayline halfway between the points of entrance and exit dose measurements[4]. The entrance dose is defined as the dose at the depth of dose maximum. The exit dose is defined as the dose at a distance of dose maximum upstream from the exit surface[11]. Dose of points on the midline and central axis were calculated using entrance and exit dose measurements. Our calculation methods consisted of arithmetic and geometric mean methods. In these methods, the midline dose is determined using only measured entrance and exit doses without using any patient information.

In arithmetic mean method, a linear decrease of dose with depth is assumed and the midline dose ($D_{midline}$) is calculated by averaging of measured entrance ($D_{entrance}$) and exit dose (D_{exit}) values:

$$D_{midline} = (D_{entrance} + D_{exit})/2$$

In some centers a more complex version of this method is applied [18] and some corrections for beam energy, patient thickness, SSD and wedge are considered. By this latter method the agreement between calculated and measured midline dose is almost less than 2%[10]. However this latter method needs additional information and was not considered in our study.

In geometric mean method, an exponential reduction of dose with depth is assumed[12, 17]. However, for using this method we had to do some corrections for the difference in distance between midline and entrance or exit points by applying inverse square law. Finally, the midline dose can be calculated:

$$D_{midline} = (D_{entrance} \cdot D_{exit})^{1/2}$$

Thorax phantom and irradiation techniques

We used a Theratron 780C (Theratronix, Canada) Co^{60} machine for our irradiations, which uses gamma rays with energies of 1.17 and 1.33 MeV for irradiation.

An inhomogeneous thorax phantom was used for dose measurements (figure 1). This phantom was designed and constructed by Mesbahi *et al.* and used in several studies for dosimetry purposes[18,19]. This phantom was made of polyethylene (ρ=0.93 gcm^{-3}), cork (ρ=0.20 gcm^{-3}), and Teflon (ρ=2 gcm^{-3}) as substitutes for soft tissue, lung and spine respectively. A Farmer-type Ionization Chamber (IC) with sensitive volume of 0.6 cc

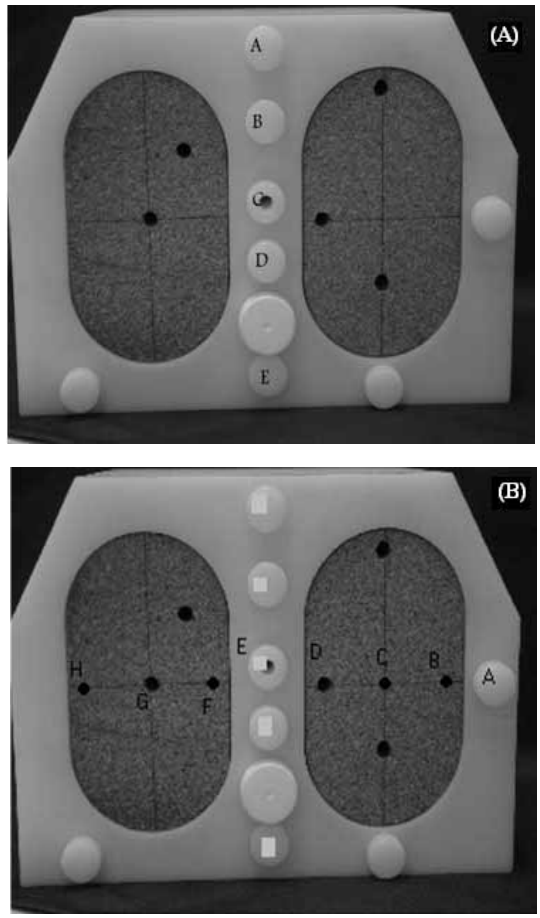

Figure 1. The anatomic thorax phantom and points used for ionization chamber measurements. (A) Anterior field and (B) lateral field.

was used for output calibration of Co^{60} machine and dose measurements in thorax phantom. For entrance and exit dose measurements, we used Victoreen diode dosimetry system (model, 5-595). This system consists of an electrometer and a diode dosimeter suitable for dose measurements in energy range of 1-4 MeV. According to the manufacturer, the stability of this system against temperature variation in range of 20-37 °C has been less than 0.5%. The diameter and volume of sensitive silicon material was 5 mm and 0.2 mm^3, respectively. A build up cap made of stainless steel in front surface of sensitive volume created the required build up thickness for Co^{60} photon beam. The mentioned in vivo dosimetry system was calibrated by Iranian atomic energy organization and the calibration factor of 1 cGy/reading was reported for it.

Two fields were considered for our study: (1) an anterior thorax field irradiating the mediastinum and both lungs with dimension of 15×15 cm^2. (2) a lateral thorax field with dimension of 15×15 cm^2. The geometry of irradiations and points for dose measurements are shown in figure 1. All irradiations were performed at a SSD of 80 cm. The output of our machine was 157 cGy/min and the irradiation time was 1 minute. The entrance and exit doses were measured using diode dosimeters, and the dose of points in midline and central axis of beam were measured by IC. The IC Readings were corrected for temperature and pressure and converted to absorbed doses using calibration factor ($N_{D,W}$):

$$\text{Dose (cGy)} = \text{Reading} \times C_T \times C_P$$

The doses of points on the midline and central axis of beam were calculated using both arithmetic and geometric mean methods from measured entrance and exit dose values by diode dosimeter. The calculated midline and central axis doses were compared with ionization chamber measurements. The error of both methods for all measured points (by IC) was calculated using the following question:

Error % = [(Measured $Dose_{IC}$ - Calculated dose from entrance and exit doses)/ Measured $Dose_{IC}$] × 100

RESULTS AND DISCUSSION

The errors of both arithmetic and geometric mean methods comparing with IC measurements in thorax phantom has shown in table 1. In anterior field, for all points on central axis and midline, the amount of errors were significant and ranged from 9% to 19% for arithmetic mean method. The results of calculations by geometric mean method were better and for points near the midline, including points B, C, D the errors were between 1.5% and 5.8%, which showed better performance for geometric mean method. The smallest amount of errors was observed for points C and D. For point E, the error of geometric mean method was about 8%, which signified the increase of error with distance from midline. For lateral field, the error of arithmetic mean method was between 8.8% and 19%. But, for geometric mean method the amount of error was between 2.6% and 6%. For point E on midline, the error of geometric method was less than 3%. Using this method the

Table 1. The errors of arithmetic and geometric mean methods for different points on the midline and central axis comparing with measured doses by IC. (A) Anterior thorax field (B) Lateral thoax field.

A:

Points	Arithmetic mean	Geometric mean
A	11.7%	6%
B	15%	5.8%
C	13.3%	5.6%
D	8.8%	2.8%
E	13%	2.6%
F	16.4%	2.7%
G	19%	2.3%
H	18%	3.7%

B:

Points	Arithmetic mean	Geometric mean
A	11.3%	6.3%
B	10%	5.8%
C	9.9%	3.3%
D	10.3%	1.5%
E	19%	8%

maximum observed error was related to points far from the midline. For points in lung, and with distance less than 7 cm from midline, the error was less than about 5.6%. The arithmetic and geometric mean methods for midline dose are simple, and do not require any additional information. This is the advantage of these methods in comparison with the patient-dependent calculation methods. Previous studies showed that midline dose calculation methods would have acceptable accuracy for media with small amount of symmetric inhomogeneities. In a study by Beollaard *et al.* on inhomogeneous pelvis phantom with 8 MV photon beam, the arithmetic mean method have shown significant difference from actual delivered dose, and this difference have increased with distance from the midline[21]. In the present study the maximum error was observed for lateral thorax field with arithmetic mean method. This could have been due to low energy photons, and the presence of lung inhomogeneities. Some studies have shown that the error of arithmetic mean method decreases with increase of the photon energy, and the reduction in amount of inhomogeneities exist in the treatment volume[5,12,16,17]. The large errors of arithmetic mean method can be expected, since this method is simple and is not based on any realistic physical model. Therefore, this method is acceptable only for high photon beam energies, if no homogeneities are present.

Geometric mean method shows better accuracy comparing with arithmetic mean method. This is because the PDD is described by an exponential function, which is not completely correct, especially when closed to the depth of dose maximum. In a study by Beollaard et al. on midline dose calculation methods using different phantoms and photon energies, the maximum error of 3% and 5% was found for 4 and 18 MV photons respectively[22]. The results of our study showed the error of less than 3% for midline dose for both fields, which are in close agreement with the results of the mentioned study. In this method, the midline dose can be approximated by correcting both entrance and exit dose for the difference in distance to the source, comparison with midline position, and then taking the square root of product of those corrected values. However, this correction is not applicable for scattered dose component[23]. However, because the primary dose component is the most significant component of total dose, this method shows better accuracy for high-energy beams. But, in situations where the contribution of scattered dose is large, this method becomes less accurate. According to the obtained results, and the previous studies, it can be concluded that the geometric mean method is a simple and applicable method for midline dose calculations in *in vivo* dosimetry of thorax region.

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