J. Korea Asso. Radiat. Prot.
Vol. 28 No. 1 : 59~63(2003)

■ 論 文 ■

Transmission Dose Estimation Algorithm for in vivo Dosimetry

Hyong Geun Yun[*] · Soon Nyung Huh[†§] · Hyoung Koo Lee[‖] · Hong Gyun Woo[†‡] · Kyo Chul Shin[*] and Sung Whan Ha[†‡]

Department of Therapeutic Radiology, Dankook University College of Medicine*,
Department of Therapeutic Radiology, Seoul National University College of Medicine[†],
Institute of Radiation Medicine, Medical Research Center, Seoul National University[†],
Torsion Meditronics[§],
Department of Biomedical Engineering, Catholic University College of Medicine[‖]

(AOCRP-1 ORAL 발표, 2003년 3월 3일 채택)

Abstract - Purpose : Measurement of transmission dose is useful for in vivo dosimetry of QA purpose. The objective of this study is to develope an algorithm for estimation of tumor dose using measured transmission dose for open radiation field.

Materials and Methods : Transmission dose was measured with various field size (FS), phantom thickness (Tp), and phantom chamber distance (PCD) with a acrylic phantom for 6 MV and 10 MV X-ray. Source to chamber distance (SCD) was set to 150 cm. Measurement was conducted with a 0.6 cc Farmer type ion chamber. Using measured data and regression analysis, an algorithm was developed for estimation of expected reading of transmission dose. Accuracy of the algorithm was tested with flat solid phantom with various settings.

Results : The algorithm consisted of quadratic function of log(A/P) (where A/P is area-perimeter ratio) and tertiary function of PCD. The algorithm could estimate dose with very high accuracy for open square field, with errors within ±0.5%. For elongated radiation field, the errors were limited to ±1.0%.

Conclusion : The developed algorithm can accurately estimate the transmission dose in open radiation fields with various treatment settings.

Key words : in vivo dosimetry, algorithm, transmission dose, open radiation field

I. INTRODUCTION

Measurement of transmission dose is useful for in vivo dosimetry of QA purpose. The objective of this study is to develope an algorithm for estimation of tumor dose using measured transmission dose for open radiation field.

II. MATERIALS AND METHODS

Transmission dose was measured with various field size (FS), phantom thickness (Tp), and phantom chamber distance (PCD) with a acrylic phantom for 6 MV and 10 MV X-ray. Source to chamber distance (SCD) was set to 150 cm. Geometric relationship of the experiment is represented in Fig. 1. Size of single acrylic phantom slice was 40 cm x 57.5 cm with 1 cm thickness and the density of acrylic phantom was 1.17. Various phantom thickness was made by stacking phantom slices. Measurement was conducted with a 0.6 cc Farmer type ion chamber. Using measured data and regression analysis, an algorithm was developed for estimation of expected reading of transmission dose. Accuracy of the algorithm was tested with flat solid phantom with various settings. Used Tp in measurement for basic beam data were 5, 10, 20, 30, and 40 cm

for 6 MV and 10 MV X-ray. Fifteen steps of FS were used (i.e., 3 x 3, 4 x 4, 6 x 6, 8 x 8, 10 x 10, 12 x 12, 14 x 14, 16 x 16, 18 x 18, 20 x 20, 24 x 24, 28 x 28, 32 x 32, 36 x 36, and 40 x 40
cm). Used PCD were 10, 20, 30, 40, and 50 cm. So, there were 375 conditions for measurement for each X-ray energy. And Measurement was also conducted without phantom (Tp=0) for all 15 kinds of FS.

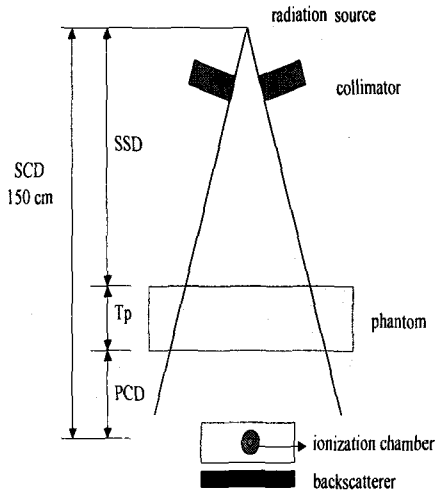

Fig. 1. Geometric relationship between radiation source, phantom, and ion chamber. (SCD : source chamber distance, SSD : source surface distance, Tp : phantom thickness,PCD : phantom chamber distance).

To exclude the influence of temperature, pressure, and output variation of linear accelerator on measurement results, more than 3 measurements were made under reference condition (i.e., FS 10x10 cm, Tp=0). Average value of measurements under reference condition was defined as reference reading (D0), and each measured values divided by reference reading were defined as corrected readings, which were used for analysis.

Estimation of tumor dose from transmission dose included two steps. First step was to estimate the output of linear accelerator from transmission dose by using algorithm (developed in this thesis). And 2nd step was to calculate the tumor dose by using of estimated output of linear accelerator and condition of irradiation (this step is routine daily work of radiation dosimetrist).

In this study, using basic measured data of 375 measurement conditions for each energy and regression analysis, an algorithm for estimation of expected reading of transmission dose was developed.

After development of the algorithm, the accuracy of the algorithm was tested with basic beam data.

And then, for systematic analysis, the accuracy of the algorithm was also tested by using carefully designed test protocol consisted of various measurement conditions different from conditions for basic measurements. Measurement conditions of the test protocols included 65 kinds of conditions which consisted of combinations of various FS (i.e., 4x4, 10x10, 17x17, 20x20, 23x23, 30x30, 38x38, 10x25, and 35x10 cm), various Tp (i.e., 5, 10, 15, 25, and 34 cm), and various PCD (10, 12, 20, 30, 40, 48, 50, and 60 cm).

III. RESULTS

1. Development of an algorithm

The algorithm consisted of quadratic function of log(A/P) (where A/P is area-perimeter ratio) and tertiary function of PCD.

D (measured transmission dose) was equated to quadratic function of log(A/P) by Taylor expansion.

i.e., $D(PCD, Tp, \log(A/P)) = D0 [a(PCD,Tp)\{\log(A/P)\}4 + b(PCD,Tp)\{\log(A/P)\}3 + c(PCD,Tp)\{\log(A/P)\}2 + d(PCD,Tp)\{\log(A/P)\} + e(PCD,Tp)]$ --- (i)

a, b, c, d, e was equated to tertuary function of PCD by Taylor expansion, respectively.

$a(PCD,Tp) = fa(Tp)(PCD)3 + ga(Tp)(PCD)2 + ha(Tp)(PCD) + ia(Tp)$ +

$b(PCD,Tp) = fb(Tp)(PCD)3 + gb(Tp)(PCD)2 + hb(Tp)(PCD) + ib(Tp)$ |

$c(PCD,Tp) = fc(Tp)(PCD)3 + gc(Tp)(PCD)2 + hc(Tp)(PCD) + ic(Tp)$ +-- (ii)

$d(PCD,Tp) = fd(Tp)(PCD)3 + gd(Tp)(PCD)2$

+ hd(Tp)(PCD) + id(Tp) |

e(PCD,Tp) = fe(Tp)(PCD)3 + ge(Tp)(PCD)2 + he(Tp)(PCD) + ie(Tp) +

The coefficients of each equations of (ii) (i.e., a,b,c,d,e) were determined by regression analysis by using Microsoft excel program.

By using equations (i) and (ii), we could calculate the transmisson dose for random FS and PCD for given Tp.

As shown by our measurement, Tp and D had exponential relationship (Fig. 2), so we could calculate the transmission dose for random Tp by using exponential interpolation.

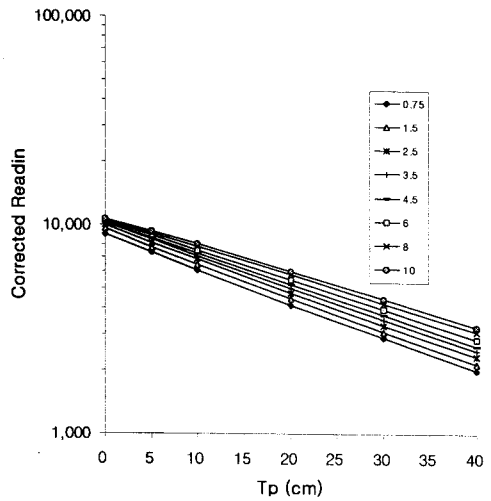

Fig. 2. Relationship between Tp and transmission dose (PCD=40 cm in 6 MV X-ray). Transmission dose decreases exponentially with Tp increment in each field size(shown as A/P in legend),(corrected reading = reading / reference reading × 10,000).

2. Test of the accuracy of the algorithm by basic beam data

Comparison of calculated reading by our algorithm and measured (corrected) reading was exemplified for the case of 6 MV X-ray, Tp=20 cm (Fig. 3). Corrected reading was increased as A/P (i.e., FS) increased, while decreased as PCD increased (the tendency became more evident for larger FS). In Fig. 3, the calculated readings (lines) and measured (corrected) readings (dots) were accurately agreed with each other

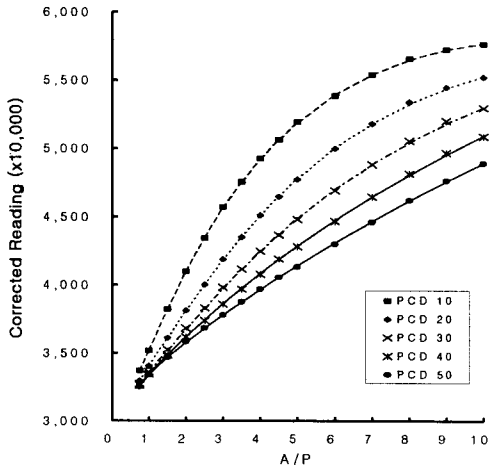

Fig. 3. Comparison between measured and estimated transmission dose using new algorithm for each PCD (Tp=20 cm in 6 MV X-ray). The marks indicate measured data and the lines indicate estimated dose.

Table 1. Distribution of error of the algorithm for transmission dose estimation in square open radiation field (6 MV X-ray).

Error range(%)	No. or used Fs	
	15*	8*
≤ -2.0	-	-
-2.0~-1.5	-	-
-1.5~-1.0	-	-
-1.0-~-0.5	-	-
-0.5~+0.5	100.0	100.0
+0.5~+1.0	-	-
+1.0~+1.5	-	-
+1.5~+2.0	-	-
≥ +2.0	-	-
mean of absolute error	0.11 ±0.09	0.12 ±0.10

* numbers indicate number of field size used for regression

For 6 MV X-ray, errors between calculated reading and measured (corrected) reading were under ±0.5% for all 375 conditions of basic measurements, the average of absolute values

of errors was 0.11%, and standard deviation of errors was 0.087% (Table 1). For 10 MV X-ray, errors were under ±0.5% for all 375 conditions, the average of absolute values of errors was 0.10%, and standard deviation of errors was 0.081% (Table 2).

Table 2. Distribution of error of the algorithm for transmission dose estimation in square open radiation field (10 MV X-ray).

Error range(%)	No. or used Fs	
	15*	8*
≤ -2.0	-	-
-2.0~-1.5	-	-
-1.5~-1.0	-	-
-1.0~~-0.5	-	0.3
-0.5~+0.5	100.0	99.7
+0.5~+1.0	-	-
+1.0~+1.5	-	-
+1.5~+2.0	-	-
≥ +2.0	-	-
mean of	0.10	0.11
absolute error	±0.08	±0.09

* numbers indicate number of field size used for regression.

To check the possibility of decrease of the number of measurement conditions for basic beam data, the coefficients in the algorithm were also determined by using of data of 8 kinds of FS instead of all 15 kinds. Errors between calculated and measured reading by using of data of 8 kinds of FS (instead of 15 kinds of FS) were also estimated. For 6 MV X-ray, errors were under ±0.5% for all 375 conditions, and the average of absolute values of errors was 0.12%, and standard deviation of errors was 0.099% (Table 1). For, 10 MV X-ray, errors were under ±0.5% for 99.7 % of 375 conditions (except one condition with error of 0.51%), and the average of absolute values of errors was 0.11%, and standard deviation of errors was 0.087% (Table 2). From these results, we could find measurement of data of 8 kinds of FS instead of all of 15 kinds of FS was sufficient for accurate formulation of the algorithm. So, we determined the algorithm by using of data of 8 kinds of FS as standard to decrease the number of measurement conditions of basic beam data.

3. Test of the accuracy of the algorithm by test protocol

Test protocol including various measurement conditions (as described in 'materials and methods') different from conditions for basic measurements was used for test of the algorithm.

For 6 MV X-ray, errors were under ±1% for 61 conditions of all 65 conditions (i. e., for 93.8% of cases), and errors were under ±0.5% for 53 conditions of all 65 conditions (i. e., for 81.5% of cases). The four conditions with errors over ±1% were the condition of FS 35x10 cm, PCD=20 cm, Tp=5 cm (with 1.26% error), FS 35x10 cm, PCD=10 cm, Tp=5 cm (with 1.58% error), FS 4x4 cm, PCD=60 cm, Tp=5 cm (with 1.79% error), FS 38x38 cm, PCD=60 cm, Tp=5 cm (with 1.25% error).

For 10 MV X-ray, errors were under ±1% for 60 conditions of all 65 conditions (i. e., for 92.2% of cases), and errors were under ±0.5% for 47 conditions of all 65 conditions (i. e., for 72.3% of cases). The five conditions with errors over ±1% were the condition of FS 35x10 cm, PCD=40 cm, Tp=5 cm (with 1.03% error), FS 35x10 cm, PCD=20 cm, Tp=5 cm (with 1.33% error), FS 35x10 cm, PCD=10 cm, Tp=5 cm (with 1.23% error), FS 4x4 cm, PCD=60 cm, Tp=5 cm (with 2.49% error), FS 38x38 cm, PCD=60 cm, Tp=5 cm (with 1.20% error).

For 6 MV, and 10 MV X-ray, those conditions with error over ±1% were clinically unfeasible conditions with extremely elongated radiation field or impractically large PCD which needed extrapolation of algorithm. So, for nearly all clinically relevant random elongated radiation fields, the algorithm accurately calculated measured dose.

IV. CONCLUSIONS

The algorithm could estimate transmission

dose with very high accuracy for open square field, with errors within ±0.5%. For elongated radiation field, the errors were limited to ± 1.0%. So, we concluded the developed algorithm can accurately estimate the transmission dose in open radiation fields with various treatment settings.

V. DISCUSSION

In radiation therapy, not only the target should be accurately irradiated but also the irradiated dose should be accurate. But in real practice, error of radiation dose is not rare, as much as 15% of radiation dose in some reports1,2,3).

To detect error in radiation dose, in vivo dosimetry is useful. But previous methods of in vivo dosimetry (i.e., entry dose measurement, invasive in vivo dosimetry, exit dose measurement) have various shortcomings.

By using transmission dose, in vivo dosimetry may become noninvasive and easy to perform daily. So, authors developed transmission dose calculation algorithm for in vivo dosimetry.

IV. REFERENCES

1. Urie MM, Goiten M, Loppke K, The role of uncertainty analysis in treatment plannning, Int. J. Radiat. Oncol. Biol. Phys., 21:91-107(1991).
2. Millwater CJ, MacLeod AS, Thwaites DI, In vivo semiconductor dosimetry as part of routine quality assurance, Br. J. Radiol., 71:661-668(1998).
3. Adeyemi A, Lord J, In audit of radiotherapy patient doses measured with in vivo semiconductor detectors, Br. J. Radiol., 70:399-408(1997).