THEORETICAL DESCRIPTION OF PERCENTAGE DEPTH DOSE CURVE FOR γ –RAY OF ^{60}Co

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(Received March 1990)

ABSTRACT

A formula describing the percentage depth dose curve for ^{60}Co γ beams is theoretically developed. The formula only needs a few data determined by measuring directly in water phantom and can be used to calculate the whole set of percentage depth dose (PDD) and tissuse air ratios (TAR) for the wide range of SSD (from 20cm to 100cm), field size (from 4cm×4cm to 20cm×20cm) and depth (from d_m to 30cm). The data calculated by the formula fits very well to the data currently used in clinics with the maximum error less than 1% and probable error of about 0.1%–0.3%. Using this formula can overcome the time–exhausting work in measurement of PDD and TAR.

Keywords: PDD SSD TAR SAD STD Dose Field

Ⅰ. THEORETICAL DESCRIPTION

1. Basic form of percentage depth dose formula

The absorbed dose $D(d,a)$ equals to the sum of primary radiation dose $D(d,0)$ and the scattered dose $D_s(d,a)$.

$$D(d,a) = D(d,0) + D_s(d,a) \quad (1)$$

where d is the depth in the phantom, a the side length of the square radiation field.

It is well know that the primary radiation dose is:

$$D(d,0) = D(d_m,0)[(f+d_m)/(f+d)]^2 \exp[-\mu (d-d_m)] \quad (2)$$

then we assume the scattered dose is following:

$$D_s(d,a) = B_1\mu_o d \exp(B_2\mu_o d) D(d,0) \quad (3)$$

Substituting Eq(2) and Eq(3) in Eq(1), we obtain

$$D(d,a) = D(d_m,0)[(f+d_m)/(f+d)]^2 \exp[-\mu (d-d_m)] \times [1+B_1\mu_o d \exp(B_2\mu_o d)] \quad (4)$$

Putting $B_o = D(d_m, o)/(d_m,a)$ into Eq(4), then Eq(4) becomes

$$D(d,a) = B_o D(d_m,a)[(f+d_m)/(f+d)]^2 \exp[-\mu (d-d_m)] \times [1+B_1\mu_o d \exp(B_2\mu_o d)] \quad (5)$$

This is the central axis depth dose formula. Then percentage depth dose formula is $P(d,a) = D(d,a)/D(d_m,a)$. So the PDD formula is

$$P(d,a) \doteq B_0[(f+d_m)/(f+d)]^2 \exp[-\mu\ (d-d_m)] \times [1+B_1\mu_0 d \exp(B_2\mu_0 d)] \quad (6)$$

where $P(d,a)$ is the percentage depth dose of a cm of square field and d cm of depth, B_0, B_1, B_2 awaiting decision constants, μ linear absorbed coefficent, d_m the depth of the maximal dose, f source–surface distance, μ_0 average linear absorbed coefficient, $\mu_0=1/\lambda$, λ is an average free length in the matter, in which a large number of photons get through. Its definition is the medium thickness in which photons path through, after that the number of the photons is reduced e times.)

2. Percentage depth dose formula for ^{60}Co

Based on a great amount of current data in Ref.[1] and experimental data for ^{60}Co, we deduce a specific form of the percentage depth dose formula for ^{60}Co as follow,

$$P(f,d,a) = P(100,d,10)+P_a(f,d,a) + P_f(f,d) \quad (7)$$

$$P(100,d,10)=B_0[(f+d_m)/(f+d)]^2 \exp[-\mu\ (d-d_m)] \times [1+B_1\mu_0 d \exp(B_2\mu_0 d)] \quad (8)$$

$$P_a(f,d,a)=[f/100]^{[(d-d_m)/d]^{10}} \cdot [1-F(a)] \cdot [5/a^2] \cdot \exp(d_m/d)^{1/2} \times [(d-d_m)/d]\sin[(d^{1/3}-10^{1/3})/d_m] \quad (9)$$

$$P_f(f,d)=B_3[(100-f)/100][(d-d_m)/d]^2\sin[1.57+(20-d)/(12+d_m)] \quad (10)$$

$$\mu=\mu_0[\mu_0(d-d_m)]^{1/12}\sin\{1.57\times[(d-d_m)/20]^{1/4}\}/F^8(a) \quad (11)$$

$$F(a)=\exp[A_0\ln(a/10)] \qquad \text{(see Ref[2])} \quad (12)$$

$$\mu_0=1/\lambda=1/(d_\lambda-d_m) \quad (13)$$

where $P(f,d,a)$ is the percentage depth dose about f cm of source surface distance and d cm of depth and a cm of square field for ^{60}Co, ($D_c(d)$ in Tabs.1–5), $P(100,d,10)$ the percentage depth dose about 100 cm of source surface distance and d cm of depth and 10 cm of square field, $P_a(f,d,a)$ a rectify term about different radiation fields, $P_f(f,d)$ a rectify term about different source surface distance, $F(a)$ the rectify coefficient of different radiation fields, d_λ the depth in that $P(100,d_\lambda, 10)=0.3679$, B_3, A_0 awaiting decision constant.

According to ICRU report, we take $f=100$cm, $a=10$cm as reference radiation field, then based on some experimental data of the reference radiation field we can get aforementioned awaiting decision constants (see II), and given $F(10)=1$, the Eq(7) can be simplified as

$$P(100,d,10)=B_0[(f+d_m)/(f+d)]^2 \exp\{-\mu_0[\mu_0(d-d_m)]^{1/12} \times\sin[0.7428\ (d-d_m)^{1/4}](d-d_m)\} \cdot [1+B_1\mu_0 d\exp(B_2\mu_0 d)] \quad (14)$$

The Eq(14) is the percentage depth dose formula under the condition of $f=100$ cm, $a=10$cm.

3. Percentage depth dose formula of source target distance for ^{60}Co

The source target distance (STD) $= f_T = f + d$, so,

$$f = f_T - d \tag{15}$$

Table 1

PDD of different fields in f = 100cm γ : ±0.16%

a(cm)	4			5			6			7			8		
d(cm)	De	Dc	△	De	Dc	△	De	Dc	△	De	Dc	△	De	Dc	△
0.5	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0
1	97.2	97.2	0	97.6	97.8	0.2	97.8	98.2	0.4	98.1	98.4	0.3	98.3	98.5	0.2
2	91.5	91.7	0.2	92.3	92.8	0.5	92.8	93.5	0.7	93.4	93.9	0.5	93.7	94.2	0.5
3	86.0	86.1	0.1	87.0	87.5	0.5	87.7	88.3	0.6	68.4	88.9	0.5	86.9	89.4	0.5
4	80.5	80.5	0	81.7	82.1	0.4	82.7	83.1	0.4	83.5	83.8	0.3	84.1	84.4	0.3
5	75.2	75.1	−0.1	76.6	76.7	0.1	77.6	77.9	0.3	78.6	78.7	0.1	79.3	79.3	0
6	70.0	69.9	−0.1	71.5	71.6	0.1	72.7	72.8	0.1	73.7	73.7	0	74.4	74.4	0
7	65.1	64.9	−0.2	66.5	66.7	0.2	67.7	67.9	0.2	68.8	68.9	0.1	69.7	69.7	0
8	60.3	60.2	−0.1	61.8	62.0	0.2	63.0	63.2	0.2	64.1	64.3	0.2	65.0	65.1	0.1
10	51.6	51.7	0.1	53.0	53.4	0.4	54.3	54.7	0.4	55.4	55.8	0.4	56.4	56.7	0.3
12	44.0	44.3	0.3	45.4	45.9	0.5	46.6	47.1	0.5	47.8	48.3	0.5	48.8	49.2	0.4
14	37.7	38.0	0.3	39.0	39.4	0.4	40.2	40.6	0.4	41.3	41.7	0.4	42.3	42.7	0.4
16	32.4	32.5	0.1	33.6	33.8	0.2	34.6	34.9	0.3	35.6	36.0	0.4	36.6	36.9	0.3
18	27.8	27.9	0.1	28.8	29.0	0.2	29.9	30.0	0.1	30.9	31.1	0.2	31.8	32.0	0.2
20	23.8	23.9	0.1	24.9	24.9	0	25.8	25.8	0	26.8	26.8	0	27.6	27.7	0.1
22	20.4	20.6	0.2	21.3	21.4	0.1	22.2	22.3	0.1	23.1	23.2	0.1	23.8	24.0	0.2
24	17.4	17.7	0.3	18.3	18.4	0.1	19.1	19.2	0.1	19.9	20.0	0.1	29.6	29.8	0.2
26	14.9	15.3	0.4	15.8	15.8	0	16.5	16.6	0.1	17.3	17.3	0	18.0	18.1	0.1
28	12.8	13.2	0.4	13.6	13.7	0.1	14.2	14.3	0.1	14.9	15.0	0.1	15.5	15.7	0.2
30	11.1	11.4	0.3	11.7	11.8	0.1	12.3	12.4	0.1	12.9	13.0	0.1	13.4	13.7	0.3
γ	±0.15 %			±0.20 %			±0.24 %			±0.20 %			±0.19 %		
Fa	0.9367			0.9518			0.9642			0.9749			0.9842		

a(cm)	10			12			15			20		
d(cm)	De	Dc	△	De	Dc	△	De	Dc	△	De	Dc	△
0.5	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0
1	98.7	98.7	0	98.7	98.8	0.1	98.8	98.9	0.1	98.9	98.9	0
2	94.3	94.7	0.4	94.6	95.0	0.4	94.8	95.3	0.5	95.1	95.5	0.4
3	89.7	90.1	0.4	90.2	90.6	0.4	90.6	91.0	0.4	91.1	91.5	0.4
4	85.0	85.3	0.3	85.7	85.9	0.2	86.2	86.5	0.3	86.9	87.3	0.4
5	80.4	80.4	0	81.2	81.2	0	81.9	82.0	0.1	82.8	83.0	0.2
6	75.7	75.6	−0.1	76.7	76.5	−0.2	77.5	77.5	0	78.6	78.7	0.1
7	71.0	71.0	0	72.1	72.0	−0.1	73.2	73.1	−0.1	74.6	74.5	−0.1
8	66.5	66.5	0	67.7	67.6	−0.1	69.0	68.9	−0.1	70.6	70.5	−0.1
10	58.1	58.3	0.2	59.4	59.5	0.1	60.9	61.0	0.1	62.9	62.9	0
12	50.5	50.9	0.4	51.9	52.2	0.3	53.6	53.8	0.2	55.7	55.9	0.2
14	44.1	44.3	0.2	45.6	45.7	0.1	47.2	47.4	0.2	49.6	49.6	0
16	38.3	38.6	0.3	39.9	40.0	0.1	47.2	47.4	0.2	49.6	49.6	0
18	33.4	33.6	0.2	34.9	34.9	0	36.8	36.7	−0.1	39.1	39.0	−0.1
20	29.2	29.2	0	30.7	30.5	−0.2	32.5	32.3	−0.2	34.8	34.6	−0.2
22	25.3	24.4	0.1	26.7	26.7	0	28.6	28.4	−0.2	30.9	30.7	−0.2
24	22.1	22.2	0.1	23.5	23.4	−0.1	25.1	25.1	0	27.5	27.2	−0.3
26	19.3	19.3	0	20.6	20.5	−0.1	22.1	22.1	0	24.3	24.2	−0.1
28	16.9	16.9	0	18.1	18.0	−0.1	19.6	19.5	−0.1	21.5	21.5	0
30	14.6	14.8	0.2	15.7	15.8	0.1	17.1	17.3	0.2	19.1	19.2	0.1
γ	±0.15%			±0.13%			±0.14%			±0.15%		
Fa	1.0000			1.0131			1.0294			1.0507		

Subsituting Eq(15) in the Eq(7), the Eq(7) can be rewritten as

$$P(f_T,d,a)=B_o[(f_T-d+d_m)/f_T]^2 \exp[-\mu(d-d_m)] \times [1+B_1\mu_o d \exp(B_2\mu_o d)]+P_a(f_T,d,a)+P_f(f_T,d) \quad (16)$$

where

$$P_a(f_T,d,a)=[(f_T-d)/100]^{[(d-d_m)/d]^{10}}[1-F(a)](5/a^2) \times \exp(d_m/d)^{1/2}[(d-d_m)/d]\sin[(d^{1/3}-2.154)/d_m] \quad (17)$$

$$P_f(f_T,d,a)=B_3[(100-f_T+d)/100][(d-d_m)/d]^2 \times \sin[1.57+(20-d)/(12+d_m)] \quad (18)$$

The Eq(16) is a percentage depth dose formula of source target distance.

It is clear, from Eq(16), that the source surface distance is different at different depth when applying source target distance treatment, then the dose rate at d_m point must be different when applying different depth treatment. It should be changed as follow

$$\dot{D}(f_T,d_m)=\dot{D}(f_o,d_m)\times[(f_o+d_m)/(f_T-d+d_m)]^2 \quad (19)$$

where $\dot{D}(f_T,d)$ is the absorbed dose rate at d_m point when f_r=STD=SAD, $\dot{D}(f_o,d)$ the absorbed dose rate at d_m point when f_o=SSD=DAD, SAD source axis distance.

Ⅱ.THE CONSTANTS

1) μ_o As mentioned above, we take $f=100$cm, $a=10$cm as a reference field, then, based on the experimental central dose curve, the depth, d_λ, at that point the dose is reduced e times, can be obtained. then we can get μ_o as follow

$$\mu_o=1/\lambda=1/(d_\lambda-d_m) \quad (20)$$

2) B_o, B_1, B_2 After μ_o is decided, still based on above experimental central dose curve, we take three measured data (for example, $d=d_m$, 7 cm or 20 cm) and may substitute percentage depth dose value of selected three depth in Eq(14). Then we solute Eq(14) and can get the values of B_o, B_1 and B_2.

3) B_3 Using μ_o, B_o, B_1 and B_2, we can easily get B_3 by following calculating

$$B_3=P(100,7,10)-P(80,7,10) \quad (21)$$

where $P(100,7,10)$ is calculating value of Eq(14) in $f=100$cm, $d=7$cm and $a=10$cm; $P(80,7,10)$ calculating value of Eq(14) in $f=80$cm, $d=7$cm and $a=10$cm.

4) A_o Firstly measure $P(100,7,10)$ and $P(100,7,20)$ and then calculate $F(10)$ and $F(20)$ in the following equations,

$$F(10)=P(100,7,10)/P(100,7,10)=1 \quad (22)$$

$$F(20)=P(100,7,20)/P(100,7,10) \quad (23)$$

where $P(100,7,10)$ is percentage depth dose measured in $f=100$cm, $d=7$cm and $a=10$cm;

$P(100,7,20)$ percentage depth dose measured in $f=100$cm, $d=7$cm and $a=20$cm.

We may substitute the values of $F(10)$ and $F(20)$ in Eq(12). Then we solute Eq(12) and can get the value of A_o.

5) *Other constants* Using the current data from Ref.[1] for ^{60}Co, we get these constants: $\mu_o=0.06258$, $B_o=0.9893$, $B_1=0.3457$, $B_2=0.0410$, $B_3=0.021$, $A_o=0.07136$.

Then, by substituting these constants in concerned formula, we can get any clinical treatment dose in the range of SSD field and depth as described above. We must recalculate these constants if measured data are different from the current data.

III. RESULTS

We give some tables (Tab.1–5) here to show calculated data comparing with current or experimental data. In these tables, D_e is the measured values of PDD, D_c is the calculated values of PDD ($P(f,d,a)\times 100$), $\triangle$ is the difference between calculated and measured ($\triangle=D_c-D_e$), γ is the probable error,

$$\gamma=0.6745\,[(\Sigma_{i=1}^{n}\triangle_i^2)/(n-k)]^{1/2} \tag{24}$$

where n is the number of compared values, k the number of awaitting decision constants. Table 1 is PDD of different fields in $f=100$cm, $P_f(100,d)=0$ in Eq(7) because $f=100$cm, Table 2 PDD of different fields in $a=10$cm, $P_a(f,d,10)=0$ in Eq(7) because $F(10)=1$, Table 3 PDD of different fields in STD=100cm, Table 4 Calculated $D_c^T(a)$ compared with measured $D_e(a)$ of appropriate SSD, Table 5 Calculated data compared

Table 2

PDD of different SSD in a=10cm γ :±0.15%

f(cm)	20			30			40			50			60		
d(cm)	*De*	*Dc*	△	*De*	*Dc*	△	*De*	*Dc*	△	*De*	*Dc*	△	*De*	*Dc*	△
0.5	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0
1	95.0	95.0	0	96.5	96.5	0	97.2	97.3	0.1	97.7	97.8	0.1	98.0	98.1	0.1
2	84.6	84.8	0.2	88.4	88.7	0.3	90.4	90.8	0.4	91.7	92.1	0.4	92.5	93.0	0.5
3	75.3	75.4	−0.1	80.9	81.4	0.3	83.8	84.1	0.3	89.7	86.1	0.4	87.0	87.4	0.4
4	67.1	67.0	−0.1	73.7	73.8	0.1	77.5	77.6	0.1	79.9	80.1	0.2	81.5	81.8	
5	59.9	59.5	−0.4	67.2	67.1	−0.1	71.5	71.5	0	74.3	74.3	0	76.2	76.3	−0.1
6	53.4	52.9	−0.5	61.2	60.9	−0.3	65.8	65.7	−0.1	68.9	68.8	−0.1	71.0	71.0	0
7	47.6	47.1	−0.5	55.6	55.3	−0.3	60.4	60.3	−0.1	63.7	63.6	−0.1	66.0	66.0	0
8	42.6	42.0	−0.6	50.5	50.2	−0.3	55.4	55.4	0	58.8	58.8	0	61.2	61.3	0.1
10	34.1	33.7	−0.4	41.7	41.5	−0.2	46.6	46.6	0	49.9	50.1	0.2	52.4	52.7	0.3
12	27.5	27.2	−0.3	34.5	34.4	−0.1	39.1	39.3	0.2	42.4	42.7	0.3	44.9	45.2	0.3
14	22.4	22.1	−0.3	28.7	28.6	−0.1	33.1	33.1	0	36.2	36.4	0.2	38.6	38.8	0.2
16	18.5	18.2	−0.3	24.1	23.9	−0.2	28.0	28.0	0	30.9	31.0	−0.1	33.1	33.3	0.2
18	15.3	15.0	−0.3	20.2	20.1	−0.1	23.7	23.7	0	26.4	26.5	−0.1	28.4	28.6	0.2
20	12.7	12.5	−0.2	17.1	16.9	−0.2	20.3	20.2	−0.1	22.7	22.7	0	24.6	24.6	0
22				14.4	14.3	−0.1	17.2	17.2	0	19.4	19.4	0	21.1	21.2	0.1
24				12.2	12.1	−0.1	14.8	14.7	−0.1	16.7	16.7	0	18.2	18.3	0.1
26				10.4	10.3	−0.1	12.6	12.5	−0.1	14.4	14.3	−0.1	15.8	15.8	0
28				8.9	8.7	−0.2	10.9	10.7	−0.2	12.4	12.3	−0.1	13.7	13.6	−0.1
30				7.6	7.4	−0.2	9.3	9.1	−0.2	10.6	10.6	0	11.7	11.7	0
γ	±0.25 %			±0.14 %			±0.11 %			±0.13 %			±0.15 %		
Fa	1.0000			1.0000			1.0000			1.0000			1.0000		

Table 2

(Continued) γ: ±0.15%

a(cm)	70			80			90			100		
d(cm)	De	Dc	△	De	Dc	△	De	Dc	△	De	Dc	△
0.5	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0	100.0	100.0	0
1	98.2	98.3	0.1	98.4	98.5	0.1	98.5	98.6	0.1	98.7	98.7	0
2	93.1	93.6	0.5	93.6	94.1	0.5	94.0	94.4	0.4	94.3	94.7	0.4
3	88.0	88.4	0.4	88.7	89.1	0.4	89.3	89.6	0.3	89.7	90.1	0.4
4	82.8	83.0	0.2	83.7	83.9	0.2	84.4	84.7	0.3	85.0	85.3	0.3
5	77.7	77.7	0	78.8	78.8	0	79 7	79.7	0	80.4	80.4	0
6	72.7	72.6	-0.1	73.9	73.9	0	74.9	74.9	0	75.7	75.6	-0.1
7	67.7	67.7	0	69.1	69.1	0	70.2	70.1	-0.1	71.0	71.0	0
8	63.0	63.1	0.1	64.4	64.5	0.1	65.6	65.7	0.1	66.5	66.5	0
10	54.3	54.6	0.3	55.8	56.1	0.3	57.0	57.3	0.3	58.1	58.3	0.2
12	46.8	47.2	0.4	48.3	48.7	0.4	49.5	49.9	0.4	50.5	50.9	0.4
14	40.4	40.7	0.3	41.9	42.1	0.2	4.31	43.4	0.3	44.1	44.3	0.2
16	34.8	35.1	0.3	36.2	36.5	0.3	37.4	37.7	0.3	38.3	38.6	0.3
18	30.1	30.3	0.2	31.4	31.0	0.2	32.5	32.7	0.2	33.4	33.6	0.2
20	26.1	26.2	0.1	27.3	27.4	0.1	28.3	28.4	0.1	29.2	29.2	0
22	22.4	22.6	0.2	23.6	23.7	0.1	24.5	24.7	0.2	25.3	25.4	0.1
24	19.5	19.6	0.1	20.5	20.6	0.1	21.4	21.5	0.1	22.1	22.2	0.1
26	16.9	16.9	0	17.8	17.9	0.1	18.6	18.7	0.1	19.3	19.3	0
28	14.7	14.7	0	15.5	15.5	0	16.3	16.3	0	16.9	16.9	0
30	12.6	12.7	0.1	13.4	13.5	0.1	14.0	14.2	0.2	14.6	14.8	0.2
γ	±0.17%			±0.16%			±0.16%			±0.15%		
Fa	1.0000			1.0000			1.0000			1.0000		

with measured data.

The measured data is from ALCYON Ⅱ, Cobalt. We use NE-2570(A) dosemeter with 0.6ml ionization chamber and water phantom. Because the measured data from the machine is different from the current data, all constants have to be decided as follow: $\mu_0 = 0.06515$, $B_0 = 0.9885$, $B_1 = 0.3557$, $B_2 = 0.0571$, $B_3 = 0.021$, $A_0 = 0.7136$.

Table 3

PDD of different fields in STD=100cm

d(cm)\ a	(cm) 4	5	6	7	8	10	12	15	20	f (cm)	$\dot{D}_T(d_m)/\dot{D}_0(d_m)$
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	1.0100
1	97.2	97.8	98.2	98.4	98.5	98.7	98.8	98.9	98.9	99	1.0202
2	91.6	92.7	93.4	93.9	94.2	94.7	95.0	95.2	95.5	98	1.0410
3	85.9	87.3	88.2	88.8	89.3	90.0	90.4	90.9	91.4	97	1.0625
4	80.3	81.9	82.9	83.6	84.1	85.0	85.7	86.3	87.0	96	1.0846
5	74.8	76.4	77.5	78.4	79.4	80.1	80.8	81.6	82.6	95	1.1075
6	69.5	71.2	72.4	73.3	74.0	75.2	76.1	77.0	78.2	94	1.1310
7	64.4	66.1	67.3	68.3	69.1	70.4	71.4	72.5	73.9	93	1.1553
8	59.6	61.3	62.6	63.6	64.4	65.8	66.9	68.2	69.7	92	1.1805
9	55.1	56.8	58.1	59.1	60.0	61.5	62.6	64.0	65.7	91	1.2064
10	50.9	52.5	53.8	54.9	55.8	57.3	58.5	60.0	61.8	90	1.2332
11	47.0	48.5	49.8	50.9	51.8	53.4	54.6	56.2	58.1	89	1.2609
12	43.3	44.8	46.0	47.1	48.1	49.7	51.0	52.6	54.6	88	1.2896
13	39.9	41.3	42.5	43.6	44.6	46.2	47.5	49.1	51.2	87	1.3192
14	36.7	38.1	39.3	40.4	41.3	42.9	44.2	45.9	48.0	86	1.3499
15	33.8	35.1	36.3	37.3	38.3	39.9	41.2	42.9	45.0	85	1.3817
Fa	0.9367	0.9518	0.9642	0.9749	0.9842	1.0000	1.0131	1.0294	1.0507		

Table 4

Calculated $D_c^T(a)$ comparing with measured $D_e(a)$ of appropriate SSD

γ :±0.18%

d (cm)\ a (cm)	4	5	6	7	8	10	12	15	20		f(cm)
	74.9	76.2	77.3	78.3	79.0	80.1	80.8	81.5	82.4	*De*	
5	74.8	76.4	77.5	78.4	79.0	80.1	80.8	81.5	82.6	D_c^T	95
	-0.1	0.2	0.2	0.1	0	0	0	0.1	0.2	△	
	50.7	52.1	53.4	54.5	55.4	57.0	58.4	59.9	61.8	*De*	
10	50.9	52.5	53.8	54.9	55.8	57.3	58.5	60.0	61.8	D_c^T	90
	0.2	0.4	0.4	0.4	0.4	0.3	0.1	0.1	0	△	
	33.5	34.7	35.9	37.0	37.9	39.6	41.0	42.8	45.0	*De*	
15	33.8	35.1	36.3	37.3	38.3	39.9	41.2	42.9	45.0	D_c^T	85
	0.3	0.4	0.4	0.3	0.4	0.3	0.2	0.1	0	△	

Table 5

Calculated data comparing with measured data

a (cm)		10			20		*a* (cm)		10			20	
d (cm)	*De*	*Dc*	△	*De*	*Dc*	△	*d* (cm)	*De*	*Dc*	△	*De*	*Dc*	△
0.5	100.0	100.0	0	100.0	100.0	0							
1	98.5	98.5	0	98.7	98.7	0	16	36.0	35.8	-0.2	41.6	41.2	-0.4
2	93.8	94.0	0.2	94.8	94.9	0.1	18	31.1	30.9	-0.2	36.6	36.2	-0.4
3	88.9	89.0	0.1	90.1	90.5	0.4	20	27.0	26.7	-0.3	31.8	31.9	0.1
4	83.5	83.8	0.3	85.5	85.9	0.4	22	23.3	23.1	-0.2	27.7	28.1	0.4
5	78.7	78.6	-0.1	81.0	81.3	0.3	24	20.4	19.9	-0.5	23.9	24.8	0.9
6	73.4	73.5	0.1	76.2	76.7	0.5	26	17.7	17.3	-0.4	21.0	21.9	0.9
7	68.7	68.7	0	72.0	72.3	0.3	28	15.4	15.0	-0.4	18.8	19.3	0.5
8	64.3	64.1	-0.2	67.9	68.1	0.2	30	13.0	13.0	0	17.0	17.1	0.1
10	55.8	55.5	-0.3	60/0	60.2	0.2	γ		±0.18	%		±0.29	%
12	48.4	48.0	-0.4	53.0	53.1	0.1	Fa		1.0000			1.0507	
14	41.5	41.5	0	46.9	46.8	-0.1							

machine: Alcyon SSD: 80cm γ :±0.23%

Ⅳ. CONCLUSION

1) The calculated data are compared with current data[1] for ^{60}Co and measured data from ALCYON Ⅱ in such wide range that the SSD varies from 20cm to 100cm, field sizes vsries from 4cm×4cm to 20cm×20cm and depth varies from d_m to 30cm. The maximum error among total calculation is less than 1% and the probable error is about 0.1%-0.3%. So that, we think we can apply the formula to calculate dose of different SSD, field size and depth for clinical treatment with an error less than 1%.

2) The formula only needs a few experimental measured numbers (only needs five measured data), so that we can largely reduce experimental numbers. It is especially convenient for SAD treatment or ARC therapy, we need not the Tissure-Air Ratio table at all.

3) We supply a superior precision formula for clinical applying computer.

REFERENCES

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