------Raf. Jour. Sci., Vol. 19, No.3, pp 69- 77, 2008------

A Simple Mathematical Model to Calculate Dose Distribution of the Co-60 Beam

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(Received 21/11/2007 ; Accepted 26/5/2008)

ABSTRACT

The measurement of dose distribution for any radiotherapeatic device is essential for good treatment planning. Therefore, dose distribution were measured for the field size [F.S = (10x10)cm²], then we use mathematical equation according to Fermi-Dirac distribution law after modified it, in this equation two parameter (k) and (n) are directly related to the field size (a), and the depth (d). So we can contract a theoretical curve by calculating (k), (n) and putting them in to this equation.

حساب توزيع الجرع لحزمة Co-60 باستخدام نموذج رياضي بسيط

الملخص

يعد قياس توزيع الجرع لأي جهاز خاص بالعلاج الإشعاعي ذو بعد أمرا أساسيا لغرض الحصـول على علاج منتظم ودقيق. لذا قيس توزيع الجرع باستخدام المجال (10x10) cm² وبعـدها تـم اسـتخدام معادلة تعتمد على قانون التربيع العكسي ل فيرمي – ديراك مع إجراء تحوير فيهـا، حيـث تـم الـربط المباشر بين عاملين هما (k),(n) بين كل من عرض المجال (a) من جهة وبين العمـق (d) مـن جهـة أخرى. وعلى هذا الأساس نستطيع أن ننشى منحنيا رياضيا وذلك بحساب كل من (k),(n) ووضعها فـي هذه المعادلة.

INTRODUCTION

When the (percentage depth dose) has been charted for many points in the tissue equivalent phantom and the points of similar depth dose connected by lines, a series of isodose curves is obtained. Such curves shows, in detail the distribution depth dose not only on the central axis, but at all points within the beam and outside the geometric edge of the beam (Selman, 1976). Figure (1) shows the way we used to obtain isodose curves.

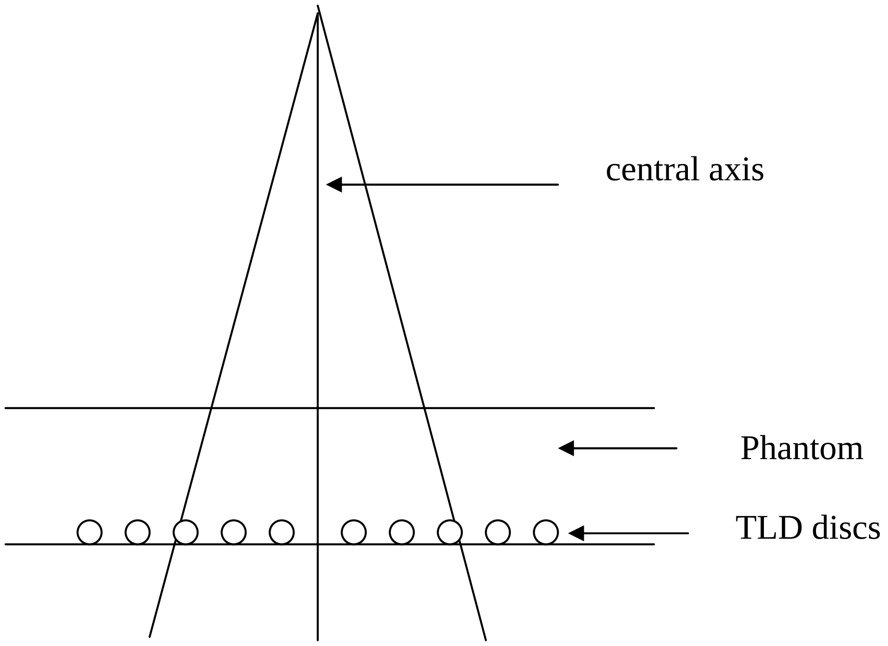

Fig. 1: Isodose curves as it measured in Co-60 unit.

There are many ways to calculate isodose distribution, one of them is using computers. In the past several papers have been published on the application of modern computers to radiation dosimeters in radiotherapy, (Sterling *et al.*, 1963), and (Bently, 1964).

In general all these methods are dealing with the dose distribution on one place, (Van de Given, 1965) introduced a theoretical model by which the computation of two and three dimensional in water equivalent media, obtained with both stationary and moving beam techniques with Co-60 radiation, becomes possible.

(Thomas, 1970) describes a new expression for the calculating of percentage depth dose for various photon beam (1.25 MeV, 4 MeV, 8 MeV, 15 MeV) and two (SSD) (source surface distance) (80 cm, 100 cm) the expression consist of two terms, the firs term gives the primary contribution together with the any back scatter and the second term represents the forward secondary scatter.

(Milan and Bentley, 1974) describes a method of beam tabulation designed to minimize the amount of data stored in the computer and suitable for a wide variety of the beam.

This method has been found to give accurate results in all parts of filtered or unfiltered beams produced by Co-60 and by (6 MeV) and (8 MeV) linear accelerator, and this method has been further developed to compensate for tissue in homogeneities such as bone and lung, with little reduction in speed of calculation.

In the next year (Kornelesn and Young, 1975) describe empirical equation which has originally developed to fit Co-60 depth dose data but by fitting data from the British journal of radiology, they have shown that it can also be used at both lower and higher energies. they uses three equations to estimate isodose in three different regions these regions are: within the beam, within the penumbra and outside the beam.

Treatment with the megavoltage electron beams is ideal for irradiating shallow seated tumors because of their limited range in tissue. However, the treatment of extended areas with electron often required the use of two or more adjacent fields. To overcome this problem, several authors have proposed techniques for matching electron beam edges in such way as to make the overlap region as uniform as possible. The simplest approach to the problem is to optimize the skin gap between the two adjacent electron field edges (Bange, 1978).

An excellent description of the problem of electron beam matching and the aims of beam - edge modification is given by (Kalend *et al.*, 1985), who proposed, comb-shaped beam edge modifier made of a low melting – point alloy. But because of the precision needed in the fabrication and positioning of the device this technique is difficult to implement clinically.

(Kurup *et al.*, 1992) proposes a method using plastic wedge penumbra generators. Polystyrene wedges were inserted in to the electron beam to increase the penumbra under the thick part of the wedge. These electron wedges can be designed from a few measurement, and they were quite successful in improving the dosimetry of the junction region.

(Lachance *et al.*, 1997)describes a new simple method to modify an electron beam to produce a wide penumbra and yield an excellent dose uniformity at the junction between adjacent electron fields. The mew penumbra generator consist of metal block made of Lipowitz metal and placed on the application insertion plate to stop part of the electron beam on the side of the field abutment. The result is wide and smooth penumbra, ideal for field matching.

(Sethi *et al.*, 2003) uses 3D treatment planning systems (3DTPS) to design compensating filters that, in addition to missing tissue compensating, can account for tissue in homogeneities. With a compensating filter, a uniform dose distribution can be achieved in only a selected compensation plane (CP), which is usually positioned at the target centre. In planes located above and below the (CP), resulting in non uniform dose distribution in these planes. The degree of the dose non uniformity increase with the increasing distance from the CP.

The aim of this study is to measure dose distribution for two depths (1.27 gm/cm^2) and (1.63 gm/cm^2) at field size (F.S = 10 cm) then we modify (Kornelson and Young, 1975) equation to be fit for different field sizes and different depths.

METHOD AND MATERIALS

1. Experimental Measurement :

(19) TLD discs were used for each irradiation by putting them on a Perspex phantom (which is tissue equivalent materials), then we put (3) sheets of Perspex on the top of the disc first with thickness (0.55 g/cm^2) and the others with thickness (0.363 g/cm^2) to obtain (1.27 g/cm^2) depth, and second (4) sheets first with thick ness (0.55 g/cm^2) and the others with thickness (0.363 g/cm ^{2}) to obtain (1.63 g/cm^2) depth, the source surface distance (SSD) used is (SSD = 80 cm), the field size (F.S) used is [F.S = (10X10) cm^2]. The time of irradiation is (5 min) which remained constant during the measurement, then the TLD discs were reared and annealed in order to use them

again (Al-Shammary, 2003). All the measurement were made in Co-60 unit at the nuclear medicine hospital.

2. Theoretical Calculation: Kornelson and Young (1975) develops simple general equation of the dose distribution, the Fermi-Dirac distribution law, which represented:

$$Y = \frac{1}{\text{Exp}\left[1/n \left\{ x / k - 1 \right\} \right] + 1} \qquad \ldots\ldots (1)$$

Where (k = a/2), (a) is the field size, and (n = p/2a), (p) is the size of penumbra. In this equation it becomes possible to obtained the parameters (k) and (n) graphically as show in fig. (2) (Correspondence, 1978). We modify equation (1) by inserting a new parameters: the depth (d) and the field size (a). So (n) will be equal to (n = d/a), in this way the parameters (k) and (n) are directly related to the field size and the depth. Different field sizes were used, these are (10 cm, 15 cm, 20 cm, 25 cm) for each depth.

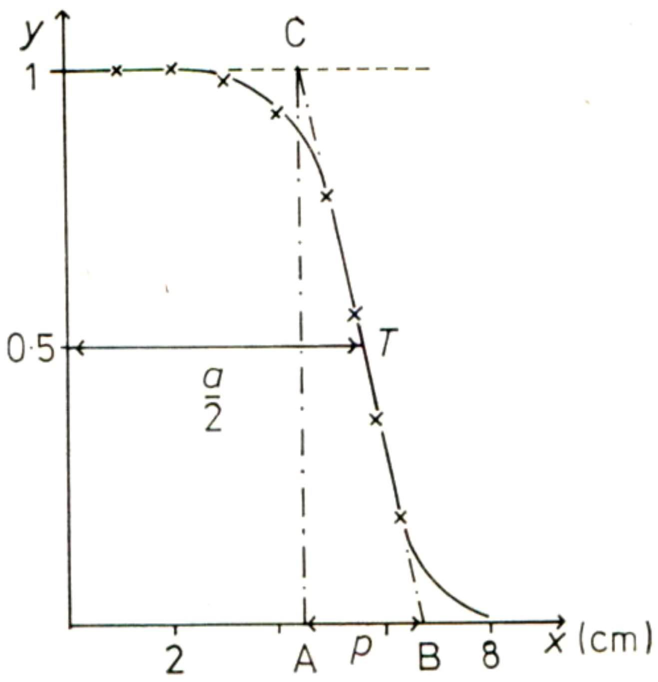

Fig. 2: Fermi-Dirac law as fitting curve.

RESULTS

Percentage depth dose for an [(10x10) cm²] field was drown as a function of the distance from the central axis for the depth (1.27 g/cm²), and for (1.63 g/cm²), then the measured data were compared with the calculated data obtained from Eq. (1) after modifying as in Fig. (3) and Fig. (4). Table (1) and Table (2) represents the measured and calculated percentage depth dose for two depths. The percentage depth dose were drown for many depths, including the two depths we measured, as shown in Fig. (5), Fig. (6), Fig. (7) and Fig (8) at field sizes (10 cm, 15 cm, 20 cm and 25 cm) respectively.

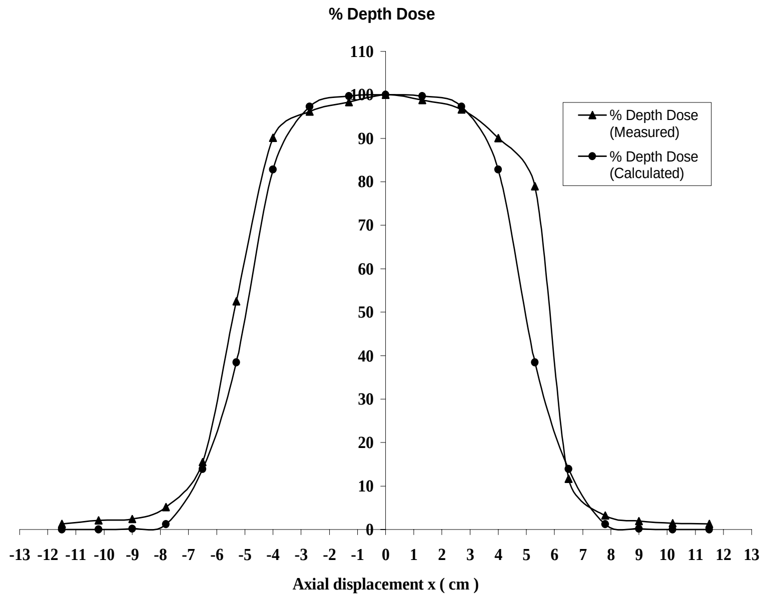

Fig. 3: Comparison of measurement and calculated percentage depth dose distribution. Depth = 1.27 g/cm² at F.S. = 10 cm.

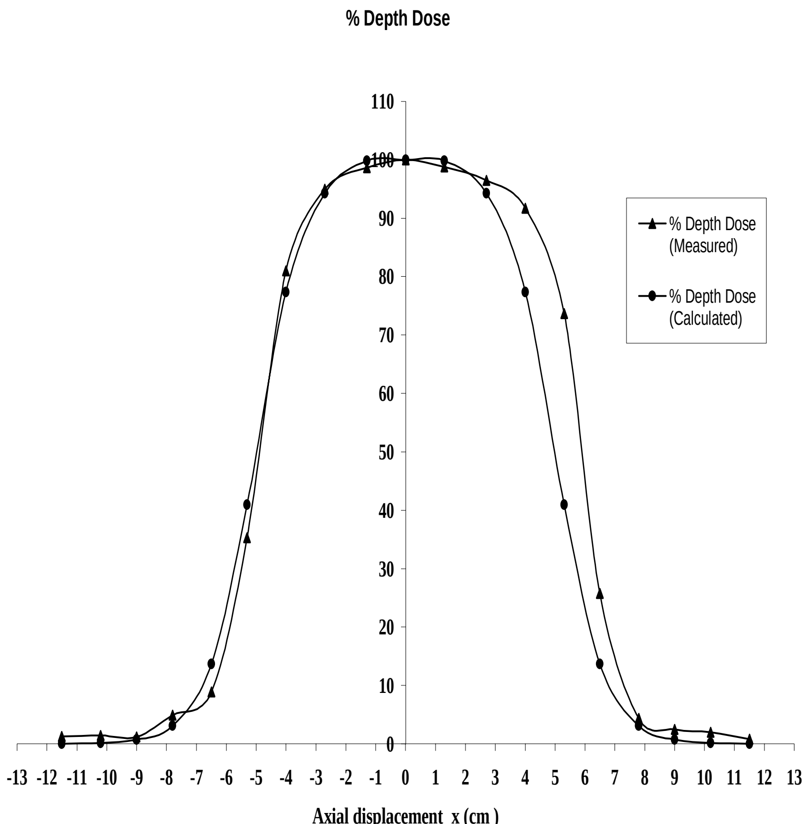

Fig 4: Comparison of measurement and calculated percentage depth dose distribution. Depth = 1.63 g/cm² at F.S. = 10 cm

	Depth = 1.27 g/cm²	

Table 1: Measured and calculated percentage depth dose, F.S. = 10 cm

Axial displacement x (cm)	% Depth Dose (Measured)	% Depth Dose (Calculated)
11.5	1.29	0.0036
10.2	1.42	0.027
9	1.94	0.184
7.8	3.23	1.2
6.5	11.65	13.9
5.3	78.96	38.4
4	90.09	82.8
2.7	96.63	97.3
1.3	98.83	99.7
0	100	100
-1.3	98.38	99.7
-2.7	96.18	97.3
-4	90.16	82.8
-5.3	52.49	38.4
-6.5	15.53	13.9
-7.8	5.17	1.2
-9	2.39	0.184
-10.2	2.07	0.027
-11.5	1.29	0.0036

Table 2: Measured and calculated percentage depth dose, F.S. = 10

Depth = 1.63 g/cm²		
Axial displacement x (cm)	% Depth Dose Measured)	% Depth Dose (Calculated)
11.5	0.78	0.034
10.2	2	0.17
9	2.47	0.73
7.8	4.36	3.12
6.5	25.78	13.7
5.3	73.68	40.9
4	91.73	77.3
2.7	96.47	94.3
1.3	98.78	99.8
0	100	100
-1.3	98.63	99.8
-2.7	94.94	94.3
-4	81	77.3
-5.3	35.26	40.9
-6.5	8.89	13.7
-7.8	4.89	3.12
-9	1.21	0.73
-10.2	1.42	0.17
-11.5	1.29	0.034

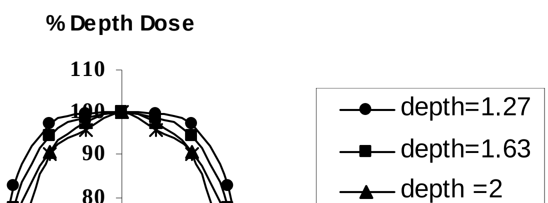

Fig. 5: Calculated percentage dose distribution at different depths.(g/cm²), F.S. = 10cm.

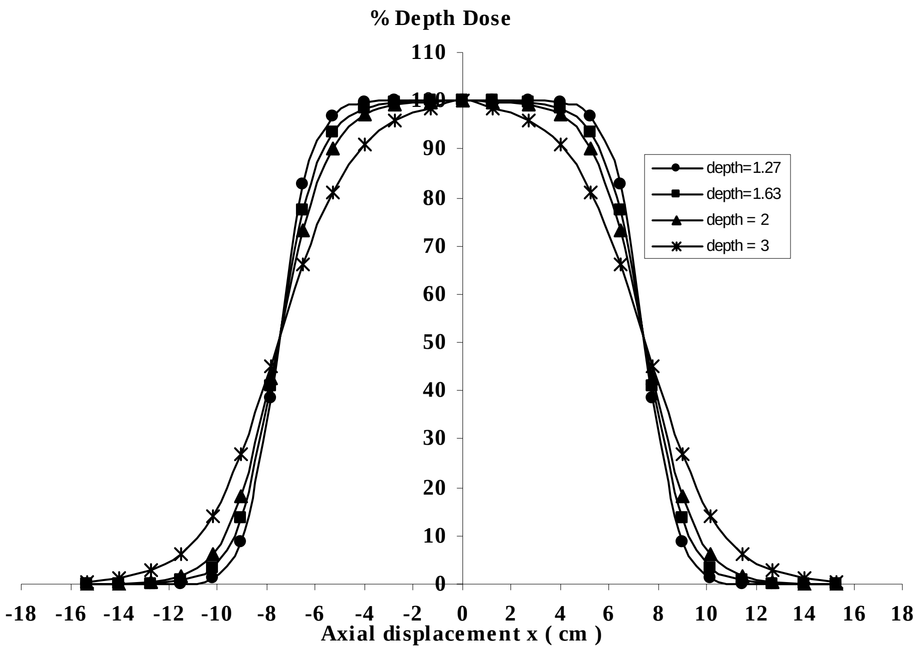

Fig. 6: Calculated percentage dose distribution at different depths (g/cm²), F.S. = 15cm.

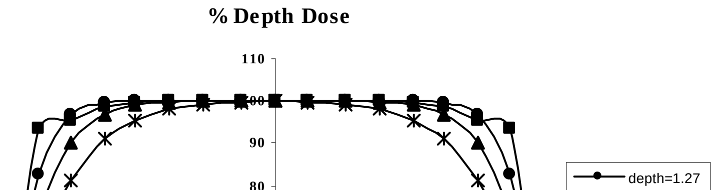

Fig. 7: Calculated percentage dose distribution at different depths (g/cm²), F.S. = 20cm.

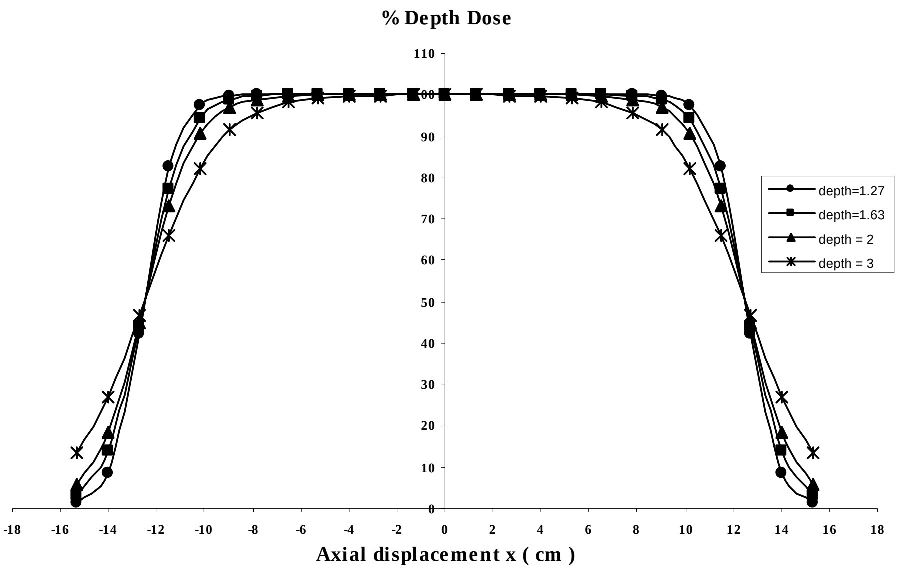

Fig. 8: Calculated percentage dose distribution at different depths (g/cm²), F.S. = 25cm.

CONCLUSION

The dose distribution can be now calculated mathematically by knowing many parameters (a), (k), (n), and (d). From Fig. (2) and (3) we see different regions: the lift which is far from the machine and the right which is near the machine, the right one shows less coincidence because the electron contamination from collimator and the accessories that put in the way of the beam. The dose distribution that measured in experimental way have many difficulties So by using a simple equation we can calculate the dose distribution whatever the field size or the depth is. The comparison of measured and calculated dose distribution showed a satisfactory an agreement.

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