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ANALYSIS OF THE VARIATION OF THE ATTENUATION CURVE IN FUNCTION OF THE RADIATION FIELD SIZE FOR 50 kVp X-RAY BEAMS USING THE MCNP-5C CODE

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ABSTRACT

The paper illustrates the use of the Monte Carlo Method, MCNP-5C code, to analyze the attenuation curve behavior of the 50 kVp radiation beam from superficial radiotherapy equipment as Dermopan2® model. The simulations seek to verify the MCNP-5C code performance to study the variation of the attenuation curve – percentage depth dose (PDD) curve – in function of the radiation field dimension used at radiotherapy of skin tumors with 50 kVp X-ray beams. The PDD curve was calculated for six different radiation field sizes with circular geometry of 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 cm in diameter. The radiation source was modeled considering a tungsten target with inclination 30º, focal point of 6.5 mm in diameter and energy beam of 50 kVp; the X-ray spectrum was calculated with the MCNP-5C code adopting total filtration (beryllium window of 1 mm and aluminum additional filter of 1 mm). The PDD showed decreasing behavior with the attenuation depth similar what is presented on the literature. There was not significant variation at the PDD values for the radiation field between 1.0 and 4.0 cm in diameter. The differences increased for fields of 5.0 and 6.0 cm and at attenuation depth higher than 1.0 cm. When it is compared the PDD values for fields of 3.0 and 6.0 cm in diameter, it verifies the greater difference (12.6 %) at depth of 5.7 cm, proving the scattered radiation effect. The MCNP-5C code showed as an appropriate procedure to analyze the attenuation curves of the superficial radiotherapy beams.

1. INTRODUCTION

The cell basal (CBC) and the cell squamous (CEC) carcinomas are skin tumors often diagnosed that motivate concerns mainly about the sun exposure, the main cause of these lesions. Such tumors can be taken to radiotherapy, because they are sensitive to radiation (radiosensitive).

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Nowadays the skin tumors treatment through radiotherapy is done predominantly by electrons beams from linear accelerators; on the other hand, in some places where there is not this technology, the treatment keeps being through of superficial radiation beams of low energy, as the beam emitted from Dermopan2® equipment, Siemens brand, with maximum energy of 50 kVp. As this equipment provides a low energy beam, it is interesting to study relevant parameters to radiotherapy and them behavior due to beam variations such as, for example, radiation field size variation. Other motivation is the current development of new intra-operative radiotherapy equipments (Intrabeam®) with exactly the same energy of 50 kVp.

As the radiation beam is incident on a patient, or on a phantom, the absorbed dose in the patient varies with depth. This variation depends on many conditions as beam energy, depth, distance from source, beam collimation system and, the most important for our study, the field size. An essential step in the dose calculation system is to establish depth dose variation along the central axis of the beam. One way of characterizing the central axis dose distribution is to normalize dose at depth with respect to dose at a reference depth, obtaining the percentage depth dose (PDD).

The percentage depth dose curve (PDD) is a radiometric parameter of the radiation beams used at radiotherapy, and it must be obtained in the commissioning of the treatment machines. In the dosimetry procedures of clinical beams, the PDD values are measured with ionization chambers suitable for the considered energies, doing the scanning of the radiation field inside a simulator (phantom).

For a small field the depth dose at a point is effectively the result of the primary radiation, that is, the photons witch have traversed the overlying medium without interacting. In this case the contribution of the scattered photons to the depth dose is negligibly small. But as the field size is increasing, the contribution of the scattered radiation to the absorbed dose increases; because this increase in scattered dose is greater at larger depths than at the depth of reference, the PDD increases with increasing field size. Since the scattering probability decrease with energy increase and the higher-energy photons are scattered more predominantly in the forward directions, the field size dependence of PDD is high pronounced for the lower-energy beam, as the 50 kVp beam used at the study.

For verify the variation of the PDD with the field size, let us use the Monte Carlo method, MCNP-5C code. Because it has been demonstrating to be an important tool for studies of the radiometric parameters of clinical beams, and for simulations of relevant problems in the radiation dosimetry.

We desire to develop computer simulations with the MCNP-5C code to demonstrate the dependence of the PDD curve against the variation of the radiation field size.

2. MATERIALS AND METHODS

The Dermopan2® model superficial radiotherapy equipment (Figure 1 and 2) was used to study the PDD dependence with the field size.

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Figure 1. Dermopan2®

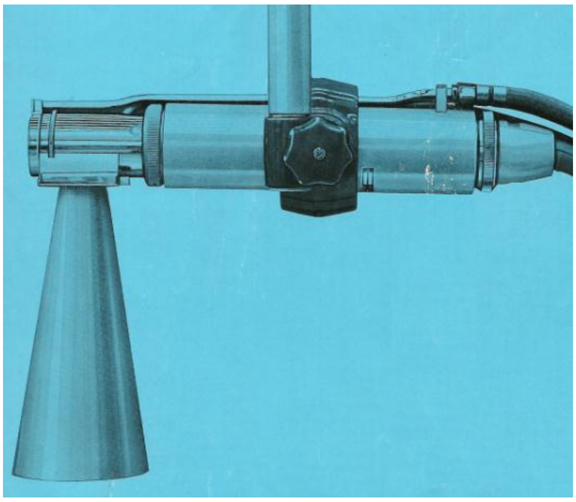

Figure 2. Dermopan2®

Figure 3 was taken from the manual for beam dosimetry; the graph represents the measured percentage depth dose (PDD) for 29 kVp (2), 43 kVp (3) and 50 kVp (4) energy, and using the Locator with a diameter of 4 cm (size of the radiation field). From the Figure 3, it was possible to build the same curves at the Origin program (Figure 4), useful for later comparison with the simulated PDD curves.

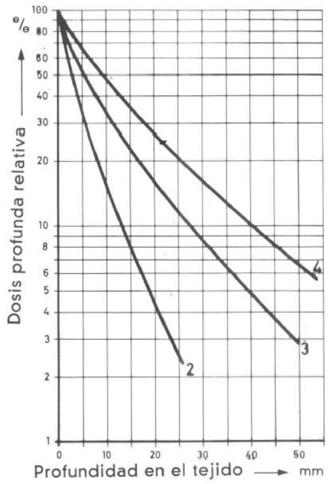

Figure 3. PDD (manufacturer's catalog)

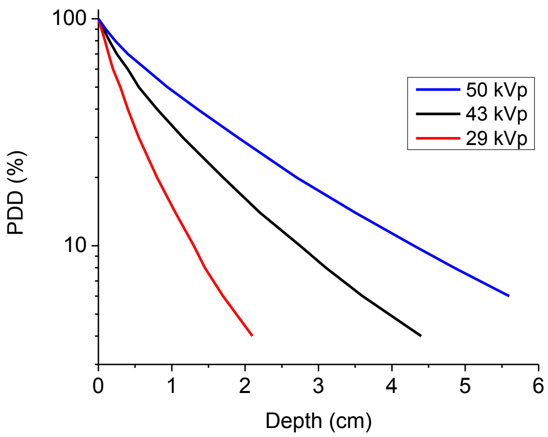

Figure 4. PDD (manufacturer's catalog) built at the Origin program

For the geometric construction (on the MCNP-5C code) of the system for calculating the PDD were considered: anode of tungsten ($^{184}W_{74}$), anode inclination of 30°, inherent filtration of beryllium ($^{9}Be_{4}$) – 1 mm, the head shield of lead ($^{207}Pb_{82}$), additional filter of aluminum ($^{27}Al_{13}$) – 1 mm, focal point of 6.5 mm in diameter, plumbiferous glass Locator with source-surface distance (SSD) of 30 cm. Figure 5 illustrates the geometric construction of all system for calculating the PDD.

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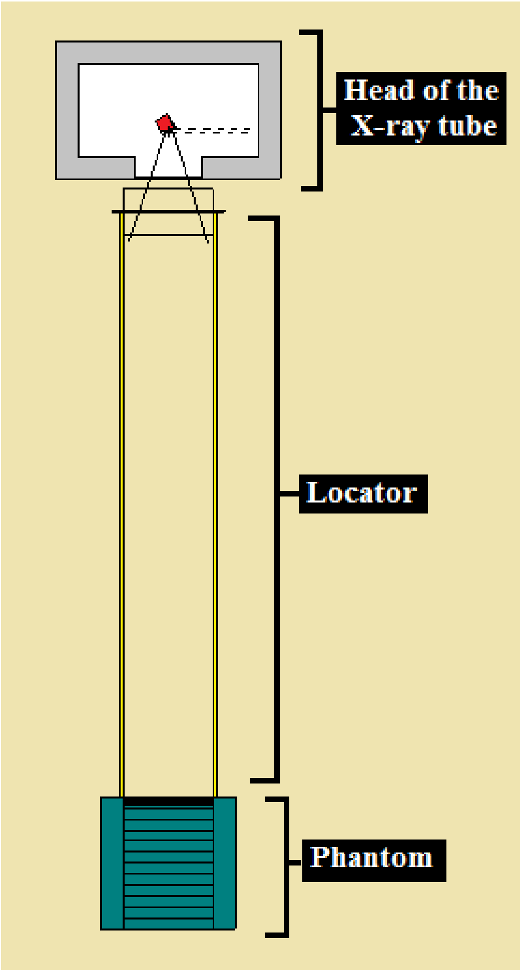

Figure 5. System for PDD simulation

The PDD express as a percentage the absorbed dose at any depth *d* to the absorbed dose at a fixed reference depth *d0*, along the central axis of the beam.

$$PDD = \frac{D_d}{D_{d0}} \times 100 \qquad (1)$$

For lower-energy X-rays, up to about 400 kVp, the reference depth is usually the surface. Sixteen layers are specified within the phantom for calculating the PDD, being the first five with 1 mm of thick and the subsequent with 0.5 cm.

The dose attenuation curve (PDD) was determined for six different radiation field size with circular geometry of 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 cm in diameter.

The behavior of the simulated PDD curves was compared with the behavior of the extracted curve from the manufacturer’s manual and used at calculations for clinical planning.

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3. RESULTS AND DISCUSSION

Through the formula 1 was possible to do the six PDD curves (Figure 6), for each circular field size.

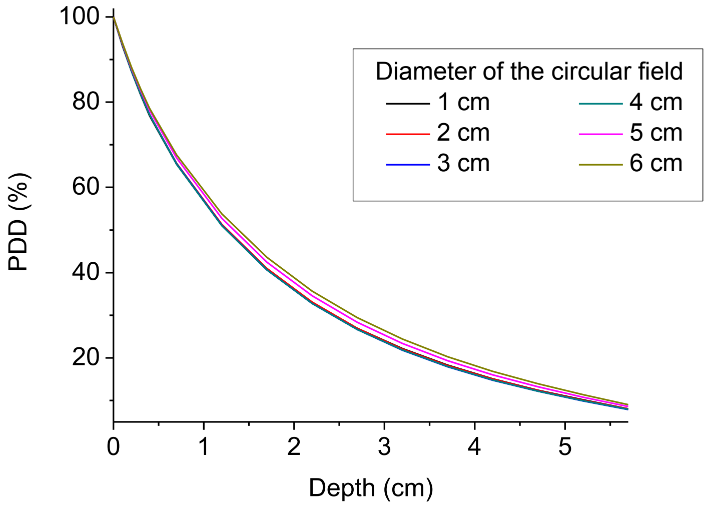

Figure 6. Simulated PDD curves in function of the field size

Table 1 shows the same PDD values of the curves presented at Figure 6, but in an easier way to analyze point to point of the curves comparing with the extracted curve from the Dermopan2® manual (PDD Manual).

Table 1. PDD values in function of the field size.

		Radiation field size – PDD and Relative error (%)											
Depth (cm)	PDD Manual	1 cm		2 cm		3 cm		4 cm		5 cm		6 cm	
		PDD	E_1	PDD	E_2	PDD	E_3	PDD	E_4	PDD	E_5	PDD	E_6
0	100,0	100,00	0,0	100,00	0,0	100,00	0,0	100,00	0,0	100,00	0,0	100,00	0,0
0,1	90,0	93,11	3,5	93,34	3,7	93,36	3,7	93,32	3,7	93,66	4,1	93,81	4,2
0,2	81,3	87,25	7,3	87,39	7,5	87,38	7,5	87,29	7,4	87,92	8,1	88,19	8,5
0,3	75,6	81,76	8,1	81,92	8,4	81,97	8,4	81,86	8,3	82,72	9,4	83,09	9,9
0,4	70,0	76,84	9,8	77,04	10,1	77,11	10,2	77,06	10,1	78,11	11,6	78,59	12,3
0,7	57,5	65,44	13,8	65,65	14,2	65,55	14,0	65,45	13,8	66,88	16,3	67,62	17,6
1,2	43,4	51,12	17,8	51,32	18,2	51,12	17,8	51,02	17,6	52,79	21,6	53,79	23,9
1,7	33,8	40,90	21,0	40,97	21,2	40,64	20,2	40,62	20,2	42,47	25,6	43,58	28,9
2,2	26,1	33,03	26,6	33,11	26,8	32,80	25,7	32,79	25,6	34,57	32,4	35,70	36,8
2,7	19,7	26,97	36,9	26,97	36,9	26,67	35,4	26,67	35,4	28,36	44,0	29,47	49,6
3,2	16,1	22,18	37,8	22,08	37,1	21,83	35,6	21,86	35,7	23,38	45,2	24,42	51,7
3,7	13,3	18,32	37,8	18,22	37,0	17,96	35,0	17,99	35,3	19,33	45,3	20,27	52,4
4,2	10,8	15,09	39,7	15,03	39,2	14,78	36,8	14,83	37,3	16,00	48,2	16,85	56,0
4,7	8,8	12,42	41,2	12,38	40,7	12,18	38,4	12,23	39,0	13,22	50,2	13,94	58,4
5,2	7,2	10,17	41,3	10,10	40,2	9,93	37,9	9,99	38,8	10,81	50,1	11,41	58,4
5,7	6,0	8,06	34,4	8,03	33,8	7,92	31,9	7,96	32,7	8,58	43,0	9,06	50,9
Mean errors (%)			23,6		23,4		22,4		22,6		28,5		32,5
Areas		189,9		190,0		188,8		188,8		196,4		201,3	

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The relative errors, E_1 à E_6, are measure between the PDD values simulated for each field size, comparing with those extracted from the manual. With the mean relative errors it is estimated that the radiation field that provides a curve closer to the desired (PDD Manual) are with 3.0 and 4.0 cm in diameter.

The area under the PDD curve is an interesting artifice to evaluate the scattered radiation by the phantom. When the radiation field increases, the contribution of scattered radiation for absorbed dose follows the same behavior. This increase in scattered radiation, or scattered dose, is greater deeply than near the surface, explaining the increase of PDD. The increases of scattered radiation can be quantified checking the areas of the curves, considerably higher, when fields of 5.0 and 6.0 cm in diameter are used.

4. CONCLUSIONS

The percentage depth dose (PDD) curves presented decreased behavior with the attenuation depth similar what is verified at the literature.

There was not significant variation at the PDD values for the radiation field between 1.0 and 4.0 cm in diameter. Therefore, the curve that is closer from manual curve is with 3.0 cm in diameter, since the error is the smallest (12.6 %).

The differences between the curves increased for fields of 5.0 and 6.0 cm and at attenuation depth higher than 1.0 cm. When it is compared the PDD values for fields of 3.0 and 6.0 cm in diameter, for example, it verifies the greater difference (12.6 %) in depth of 5.7 cm, proving the dependence of the PDD with the field size and the increase of scattered radiation.

The MCNP-5C code showed as an appropriate procedure to analyze the attenuation curves of the superficial radiotherapy beams.

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