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The Gradient of β-particles Irradiation's Energy, Produced by Linear Accelerator and its use in Radiotherapy of Cancer Diseases

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Abstract: Inonising irradiations used mostly in the treatment of tumoral deseasses are: X γ, β and e iradiations. The aim of this study is the investigation of gradient of β-particles irradiation energy. The discussion will be about radiations, produced in linear accelerators, electron energy from 5-14 MeV. It is important to know, the absorption performance, before and after, the electronic equilibrium. Weve use the function of dose gradient for iradiations β. It represents the velocity of dose change as a function of depth in tissue. From skin to maximum dose value, the increase of G-function is more accentuated for γ-rays than for β-particles while after that the G-function decreasing is less sharp for γ-rays while for β-particles it is almost promptly. This fact, allow us to use in radiotherapy not only γ-rays but β-particles too. The lasts, represents, a much more efficient tool, especially in terms of radiation protection of health adjacent tissues and organs. Finally we'll discus, about the advantages in terms of radiation protection of β-particles used in radio therapy.

Key words: Gradient, β-particles, energy, radiotherapy, cancer diseases

INTRODUCTION

When an iradiation beam, passes from a point A to an other point B, d cm. distant, the energy of beam, changes from E_1-E_2. The difference $\Delta E = (E_1 - E_2)$ is the lost energy by the interaction of beam, itself with material of tissue then gradient of beam's energy would be:

$$\frac{\Delta E}{d} = \frac{(E_1 - E_2)}{D} = G \quad (1)$$

As we can see, this mathematical function, means the rate or the velocity of beam energy reduction(decreasing); reduction which means, how quickly the beam energy passes, through interactions from the beam itself to the tissues cells.

As is demonstrated from Eq. 1, the G-function is proportional with ΔE and invers proportional with distance D, between A and B points. It means that as great is the value of G as soon, the beam loss its energy and viceversa. This dosimetric quantity, expressed in math terms is investigated in this research to increase the beams irradiation efficiency as more as possible to the tumoral cells, protecting, at the same time as much as possible the healthy tissues and organs, near and around.

As the beams irradiation lost energy is spent during the elementary interactions with the atomic structures of tissues atoms and molecules, the final product of these interactions is mostly, the ionisation of tissues itself and so, the G-function, express, the capability of certain beam irradiation for ionisation of tissues. This dosimetric quantity, expressed in maths terms is investigated in this work to increase the beams irradiation efficiency as much as possible to the tumoral cells, protecting at the same time the healthy tissues and organs near and around (Bentel, 1996; Khan, 2003; Cember, 1996).

Before doing the detailed analysis of the disscusion,we'll tell some words about the gradient function changes,caused by the interaction of irradiatios with tissues living cells. Beta (β_0^{-1}) particles or as we'll call in this research β_0^{-1} rays (or nuclear elektrons), differs by normal electrons by their origine and by energy; they are produced in atom nucleus, consequently have much more high energy than normal electrons and consequently do to the elementary negative electric charge, their specific ionising capability is higher than that of γ-rays of the same energy. And so, they are absorbed fastly, giving their energy to the living tumoral cells. Below we'll explain in detail, the mecanism of β_0^{-1} particles interaction with structures of tissue atoms and molecules.

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The last one, would be, highly more intensive as that of γ-rays because (they have electric charges and so can cause ionisation through electric interaction and) have a mass, consequently can interact through collisions (even their propability do to the too small dimensions is slightly >0). The first part of path's G-function has a fast increasing and after have reached the maximmal value will decrease with a very high velocity less or more (depend by energy of generated β_0^{-1} particles), losing whole energy, at once. So, calculating the beams energy, to reach the maximum value near before target volume we can choose the energy to give the β_0^{-1} particles energy, within the target volume. Behind the target volume, the gradient-function decreasses fastly (nearly, at once) to zero and whole the tissues or and organs located behind the tumor haven't no more risk to be irradiated. This performance of G-function, let us to use, successfully the β_0^{-1} particles irradiation of deep Target Volums (TV) giving smaller dose at the tissues before the Target Tumor Volume (TTV) giving the maximum dose within the TV and giving almost no dose behind the TV. These three principal issues as well some probably others would be the main problems to disscus within the frames of this research, trying to do as more as possible usefull, the specific carachteristics of β_0^{-1} particles vs its interaction with tumoral and health living cells.

MATERIALS AND METHODS

Material is took of from the every day typical treatment cases, using the real data of patients as well, real data of radiation's parameters. Figure 1 is shown a picture of Percentage Depth Dose (PDD) for (10×10) beam size of β_0^{-1} particles, generated in accelerator with energy of 5 MeV.

As we can see, the first part of curve that from the skin to the maximal value (which is took as 100%), increase a litle bit fastly which means has a slightly higher gradient because the differencies do to ionisation's capabilities do to almost equal energies of both irradiations have quasy the same performance. This increasing for the case shown in Fig. 1 reached the maximum value nearer, under the skin (10 mm). This fact has to do even with energy difference as well with some other factors. The second part of grafi is descendent and shown that finally the production of secondary irradiations, mostly electrons is less than absorption. So the rate balla-nce between produced and absorbed irradiations is <1(Ip/Ia<1). But the total G-function determined from maximal values to value zero for case in Fig. 1 will be less than or more than 100% in 10 mm. Qualitatively these two values can't be paragonate and

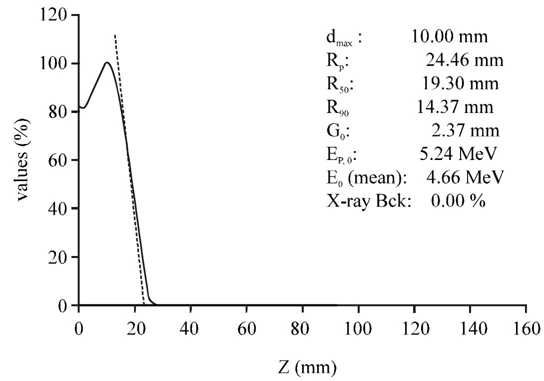

Fig. 1: PDD for electrons with energy 5 MV, field size 10×10 cm

for these reasons in generally are paragonate the volues of 80 or/and 50%. The second value, i.e., 50% in this case will be 50/20 mm 25%/cm or about 8 times more. As we can see from the Fig. 1 this rate is not constan it is an increasing function, mostly because this part of graf Fig. 1. Looking more detaily the Fig. 1 we can see that the PPD from 50-10%, changes within 3-5 mm which means in a very thin space. This allow us to calculate more exactly the zone in which there are no more radiations. So, the living health structures located behind tumor can be protected without any shielding can be shielded using rationally this fact, choosing the appropriate energy of β_0^{-1} particles in mode to loos all its energy, exactly there where is the retrolocated margin of tumor. This mode of use gives the possibility not only to protect the strucures behind which are involved in the irradiations path but decreasing the integral dose, protecting better the organs or/and tissues located behinde the tumor. This kind of protetion isn't possible where the irradiation is performed with γ-rays. This is of a great advantage for radiotherapy of tumor's irradiation with β_0^{-1} particles than with γ-rays.

RESULTS AND DISCUSSION

The sharp fall of dose value, in the case of a β_0^{-1} particles, beam is fruitfully used in radiotherapy to protect the health tissues while increasing the energy increase the depth under the skin where is achieved the maximum dose value. while for β_0^{-1} particles, the distribution is more accentuated, i.e., the depth where is achieved the maximal dose is more deeply (up to a certain energy) and this is of e great im-portance but of a huge importance is in the case of electrons (ne) the fact that behinde the closed zone, the intensity of irradiation, immediately falls, i.e., falls within some milimeters.

And we get advantage to "have in our hands" like a shell which enter in the patient skin with a certain energy and intensity which increse up to maximum dose value in a certain depth, gives its energy whole into a certain zone, behinde which its energy becomes zero.

If we as physicists are able to 'put' the tumor, within the borders of maximal dose zone we do at the same time some, extremely usefull therapeutic action, from which the more important are: depending by energy, the skin dose, in generally will be 10-50% smaller than tumoral dose given which on the other site allow us to deliver higher doses as above is mentioned without any damages and injuries of skin and other structures located in the path of radiation beam.

Protecting in any case, every tissue or/and organ which is located behind the tu-mor, giving us more possibilities to achieve higher doses and giving us the possi-bility to reduce significantly the integral dose (Xhafa *et al*., 2014)

The most important discussions argument to keep in mind is: to do maximal caution, necessary to realise, the Quality Assurance (QA) treatment to perform a correct treatment being this one, always more than necessary. This becomes more important even, imperative because the treatment is based in high energy radiations which if are used without necessary precaution and attention can becomes not efficient or even dangerose for the patient. To avoid such kind of accidents, it is more than necessary to do a good simulation and after this to do the controlls for any patient, simulating in details every step before the treatment itself. All the parameters must be controled, using an highly exact quality controll, an exact simulation of individual characteristics of each patient.

Especially for β_0^{-1} particles which maximal value is too sharp that means is reached within a small space or in other words is an accentuated maximum is very important, to do an highly exact simulation and preparatory or prior measu-rements to assure that particles energy 'explosion', becomes, into this close zone. Otherwise, the release of such energy, outside the calculated tumor zone, becomes, not only useless but twice dangerous; both for tumor's miss delivery of radiation dose and for delivery of its to the health tissues, causing its injury.

CONCLUSION

From the skin, to the maximal value of PDD for the same beam size, energy, etc., the G-function of both types of irradiations are almost the same with a slightly more advantage for β_0^{-1} particles. The energy dependence is more accentuated for β_0^{-1} particles and increase in depth as well in the surface zone of maximal dose is proportional with the increasing of energy.

The G-function, after the maximal dose value is a descending function, much more accentuated for β_0^{-1} particles than for γ-rays. So, the β_0^{-1} particles irradiation generated in accelerators can be used more effi-ciently, "exploding" whole their energy within the space location of tumor. This enables, almost perfectly the protection of behind tumor structures.

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