PROTON THERAPY: RIDGE FILTER IMPROVEMENTS FOR SAKE OF THE DOSE CONFORMITY

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Abstract

The method of passive scattering in proton beam therapy has some benefits and drawbacks. One of the drawbacks is the formation of hot lesions in the proximal region beyond the borders of the target volume. It leads to the rise of the integral dose of irradiation and lowers the irradiation conformity.

To date, a solution to this problem has been proposed by some other authors in the form of a multi-layer energy filter. Such a filter has a different amount of material and provides different energy modulation at different impact parameters. Nevertheless, the design of that device leads to an increase in the dose within the planned target volume, which may be critical in some cases. We propose a different design of the depth dose formation device – a composite ridge filter. Our solution allows changing the Bragg peak modulation width by eliminating the selected elements of the energy modulating ridge, while further changing the radiation intensity in the given target region due to the beam absorption. In our previous study, we have performed a Monte-Carlo simulation and obtained a spherical contour of 95% isodoses. Now we have developed a method for more accurate selection of device geometry, thereby reducing the controlled level of isodoses to 90% and lower. We continue our calculations to improve the conformity of irradiation and prepare experimental tests with proton beams of INR linac.

DOSE FORMATION METHODS OF PROTON THERAPY

Proton therapy is a progressive method of radiotherapy. The main benefit of this technology is a form of its depth dose distribution involves the increase of energy deposition with depth and a sharp fall-off after a specific region called Bragg peak [1]. The depth of the peak depends on the initial beam energy so it allows irradiating a deep-seated target while sparing surrounding healthy tissues.

In proton therapy, there are two essential methods of dose formation. The first way is to deflect a narrow beam by the magnetic fields to irradiate the target point by point. This technique is called a « pencil beam scanning method » and is known as the most accurate way to irradiate the target conformally. However, this method does not allow to irradiate the whole target simultaneously. It may lead to the heterogeneity of dose distribution and a local overdose of several parts caused by uncontrolled tissue movement. The second technology involves the installation of various objects on the beamline. These tools wide the beam by scattering and spread out the Bragg peak (SOBP) by changing the energy spectrum. This method is called « passive scattering », one of a possible formation system is shown in Fig. 1. This method is cheaper in comparison with the first one and allows to irradiate the whole area with a single field. Nevertheless, it struggles from the stray neutron radiation caused by the interaction with the beam delivery system. Also the «passive scattering» method leads to the emergence of overdosed region beyond the borders of the target volume (shown as red lines in Fig. 1). These problems reduce the quality of proton therapy treatment with passive scattering.

POSSIBLE SOLUTION

One of the possible solutions to rule the proximal edge of dose distribution is a construction of Multi-layer ridge filter [2]. The idea is to control the width of SOBP in local regions by increasing the number of layers of thin ridge filters as shown in Fig. 2. This method copes with the given goal of changing the radiation field form but leads to an increase in the dose in the narrowing regions of SOBP (Fig. 2). Thus, to decrease unnecessary influence the lateral beam profile has to be changed.

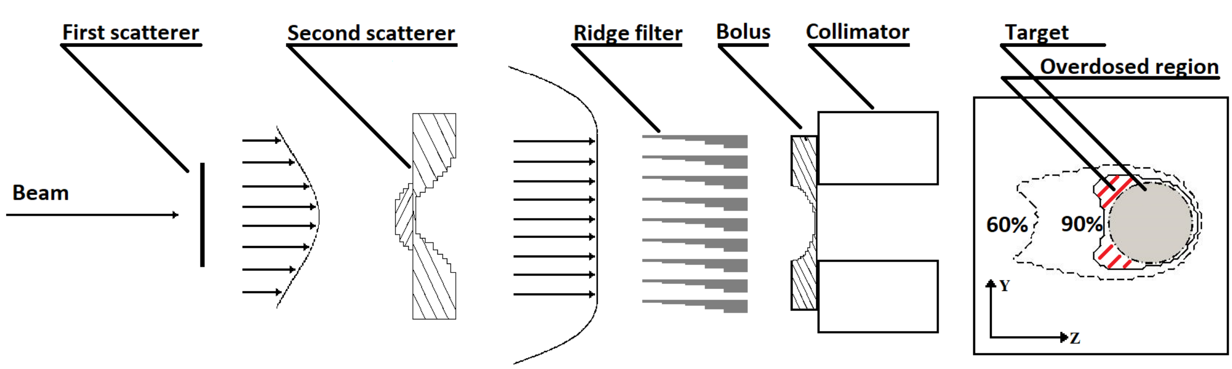


Figure 1: Passive scattering dose delivery system.

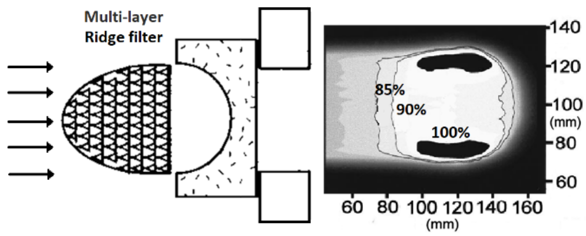


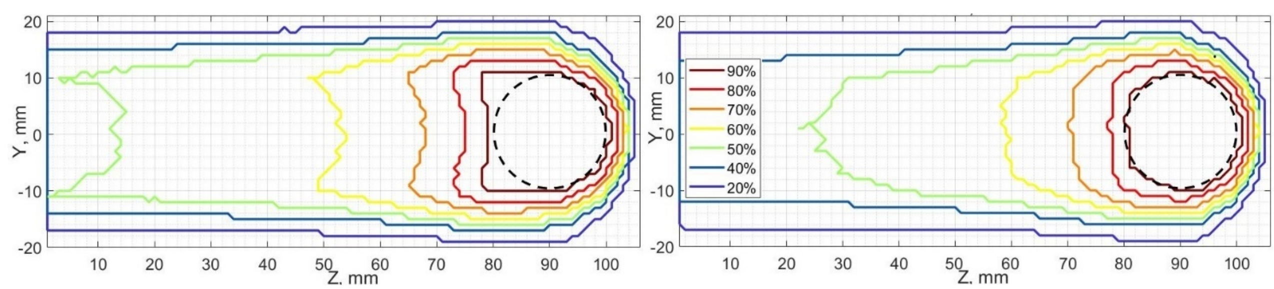
Figure 2: Multi-layer Ridge filter.

As it is said the proximal edge of dose distribution can be modified with control of the beam lateral intensity and a construction of depth dose formation device. We concluded that this could be achieved by combining an additional degrader with a traditional form of ridge filter. We called the new device a Composite ridge filter.

COMPOSITE RIDGE FILTER

The new device construction consists of two components. The first one is a traditional ridge filter represented by a number of stairs. Each element of a stair, called "step" is a degrader with a known thickness. A proper combination of steps allows forming a SOPB. We can adjust the form of SOBP in a region by blocking a step declining its contribution in the total dose distribution. It can be done by installation of dense degrader in addition to the filter element and this is implimented by the second component of the device.

An example of the effect of composite ridge filter is shown in Fig. 3. The left picture (a) represents the dose distribution achieved with the installation of the traditional filter and the right one corresponds to the formation system with the device modification (b). The dose distributions were achieved with a series of calculations with the help of the original Monte-Carlo code SRNA [3]. As shown below in Fig. 3(b) the installation of Composite ridge filter allows reducing unnecessary radiation in a region beyond the proximal edge of the target. The isodose of 90% corresponds a circular form of the target.



a) b)

Figure 3: Dose distribution with traditional filter (a) and composite ridge filter (b).

CONCLUSION

The proposed construction of the device for the dose distribution formation allows controlling the dose in the region located in front of the target. The new device will improve the compliance of the irradiation field with the shape of the irradiated object, thereby improving the quality of proton radiotherapy.

In our previous study [4], we have performed a Monte-Carlo simulation and obtained a spherical contour of 95% isodoses. At this moment we have developed a method for more accurate selection of device geometry, thereby reducing the controlled level of isodoses to 90% and lower. We continue our calculations to improve the conformity of irradiation and prepare experimental tests with proton beams of INR linac.

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