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SOME THOUGHTS ON CONFORMAL PROTON RADIO THERAPY

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Abstract

A new method of conformal proton radio therapy utilizing a variable energy modulation ridge filter is presented and applicability to the proposed radio therapy facility at the AGS Linac is discussed.

Introduction

One of the advantages of proton therapy is to have a favorable ratio of peak-to-plateau radiation compared to the conventional radiation therapy with photons or electrons. The most commonly used method of irradiating tumors is to spread the proton beam passively by means of double scattering, or a scatterer and an occluding ring. A compensator (bolus) placed in front of the treatment site matches the distal shape of the treatment volume to the range of the range of the incident proton. The depth or thickness of the tumor is accommodated by spreading the Bragg peak by means of a range filter (or modulator). A comprehensive description of various schemes is presented in the report of the Berkeley group and in its references.[1] In this way, the irradiated volume is a cylinder whose shape is defined by the patient collimator (the maximum shape of the tumor in transverse dimension to the beam) and the height matching to the maximum thickness of the tumor along the beam. Figure 1a schematically shows the scheme. There is a significant amount of collateral radiation, especially on the proximal side of the treatment volume.

An improved scheme is shown in Figure 1b. Here, the irradiation is done with a sequence of energy layers. A small range modulator controls the width of the Bragg peak. A set of dynamic collimators is used to shape the transverse dimension of the given energy layers. The scheme needs a complicated multileave collimator system. Another scheme is to make a raster scan with preprogrammed variable speed in order to compensate for the plateau radiation left by distal end of irradiation . The scheme requires stringent accuracy and control of the raster scanning magnets and uniformity of the extracted beam intensity.

A voxel-by-voxel irradiation is the method that divides the treatment volume into many cubicles (voxels) and each cubicle is treated with the Bragg peak. It is the best way to irradiate the treatment volume provided the proper seam matching between the voxels in three dimensions. However, because of the large number of voxels one has to deal with, it may require a long irradiation time, especially for machines with a poor duty factor like the AGS Linac.

Variable Ridge Filter Method

The method proposed in this note is to irradiate the treatment area in pixels (two-dimensional squares). The thickness along the beam direction is accommodated by means of range modulation with a ridge filter. The ridge filter is variable in the transverse dimension corresponding to the treatment volume thickness of the particular pixel. The amount of the radiation for each pixel can be predetermined according to the thickness. The variable ridge filter can be built by assembling a mosaic of ready-made ridge filters of pixel size. The scheme is shown schematically in Figure 2. Because only two-dimensional scanning is needed, the treatment time can be shortened by up to an order of magnitude compared to a voxel-by-voxel irradiation. A range compensator can be placed to match the distal end of the tumor if the incoming beam has a fixed energy. If the proton beam is capable of variable energy, the distal shape is accommodated by the incoming energy of the beam.

Application to the AGS Linac

The AGS Linac will be operating, after an upgrade, at a repetition rate of 7.5 Hz. With such a repetition rate, a voxel-by-voxel operation on the order of one thousand voxels would take a prohibitively long time, but a pixel-by-pixel operation on the order of one hundred pixels may be possible. In order to insure the accurate delivery of protons in each of the pixels, one can consider a binary method of delivery. The first pulse delivers one-half of the intended dose, the second pulse delivers one-half of the remaining dose (1/4 of the dose), and the third delivers one-half of the remaining dose (1/8 of the dose), etc. The sixth pulse completes the dose, which is about one percent of the intended dose. The ionization monitor decides what the accumulated dose at the pixel has been, and what the next dose should be. The dose variation can be achieved by the mean of the pulse length. Two sets (in order to insure the cut-off time) of kicker magnets with about one microsecond rise time could control the pulse length and the dose. During the 130 milliseconds between pulses, the control system calculates the timing for the next pulse and executes the radiation. Each pixel can be completed with six or seven Linac pulses. A reasonably sized tumor can be completed in about 100 seconds.

Reference

1. W.T. Chu, B.A. Ludewigt, T.R. Renner, Instrumentation for Treatment of Cancer Using Proton and Light-Ion Beams, LBL-33403, 1993.

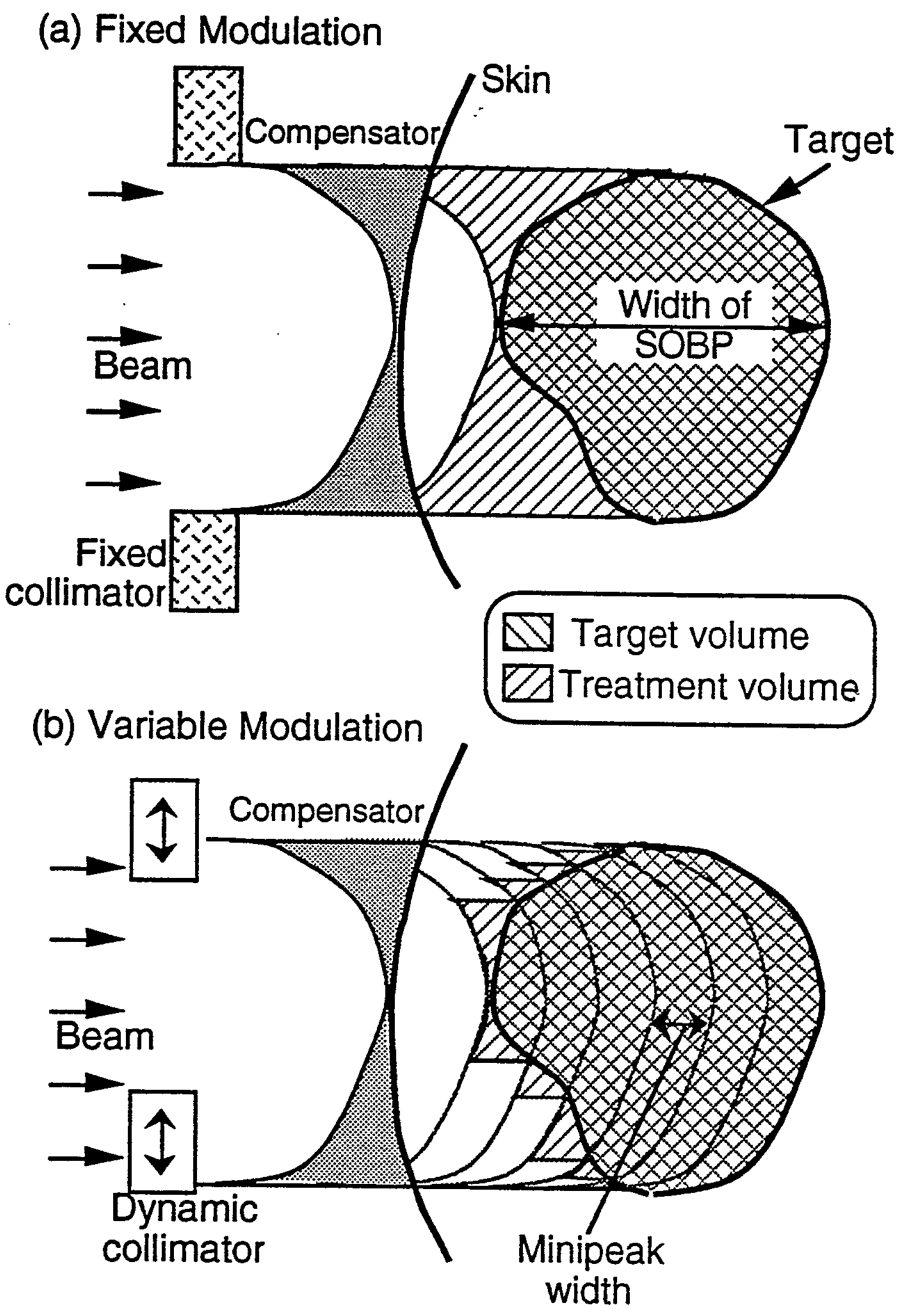

Figure 1a. Fixed energy modulation scheme.

Figure 1b. Dynamic multi-leaf collimator scheme.

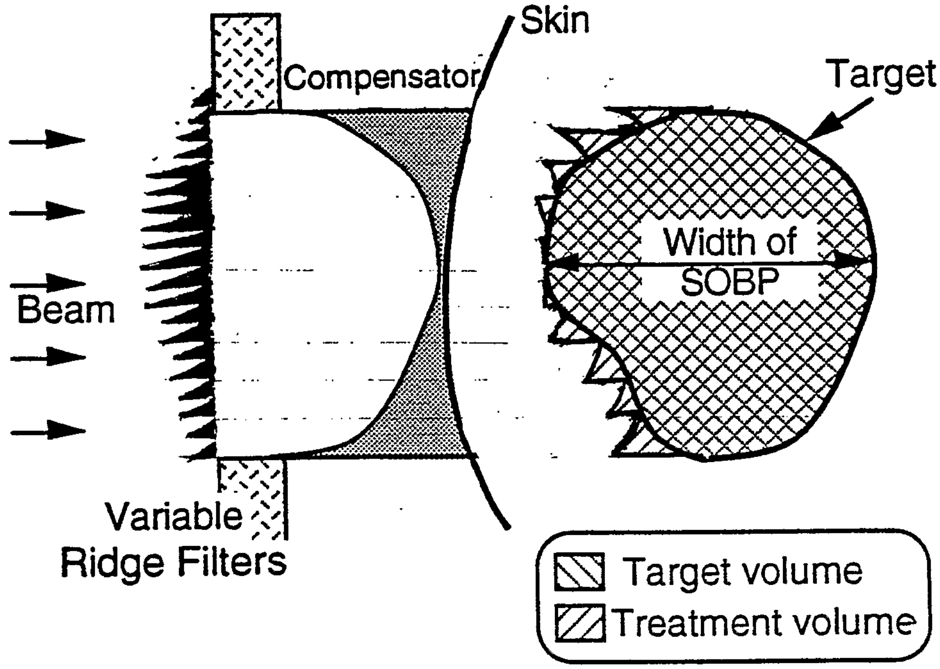

Figure 2. Variable range modulation scheme.