
Abstract
PURPOSE:
To review the current limits on the efficacy of radiotherapy (RT) due to technical factors and to assess the potential for major improvements in technology.

METHODS AND MATERIALS:
The method of this review was to assess the efficacy of current RT in general terms; strategies for improving RT; historical record of technological advances; rationale for further reductions of treatment volume; and importance of defining and excluding nontarget tissues from the target volume. The basis for the interest in proton beam RT is developed, and the relative dose distributions of intensity-modulated radiotherapy (IMRT) and intensity-modulated proton RT (IMPT) are discussed. The discovery of the proton and the first proposal that protons be used in RT is described. This is followed by a brief mention of the clinical outcome studies of proton RT. Likely technical advances to be integrated into advanced proton RT are considered, specifically, four-dimensional treatment planning and delivery. Finally, the increment in cost of some of these developments is presented.

RESULTS:
For definitive RT, dose limits are set by the tolerance of normal tissues/structures adjacent or near to the target. Using imaging fusion of CT, MRI, positron emission tomography, magnetic resonance spectroscopic imaging, and other studies will result in improved definition of the target margins. Proton beams are likely to replace photon beams because of their physical characteristics. Namely, for each beam path, the dose deep to the target is zero, across the target it is uniform, and proximal to the target it is less. Proton therapy can use as many beams, beam angles, noncoplanar, and dynamic, as well as static, intensity modulation, as can photon plans. The ability for much greater accuracy in defining the target position in space and then maintaining the target in a constant position in the radiation beam despite target movement between and during dose fractions will be possible. The cost of proton RT will be modestly higher than comparable high technology photon therapy.

CONCLUSION:
The technology of RT is clearly experiencing intense and rapid technical developments as pertains to treatment planning and dose delivery. It is predicted that radical dose RT will move to proton beam technology and that the treatment will be four dimensional (the fourth dimension is time). The impact will be higher tumor control probability and reduced frequency and severity of treatment-related morbidity.