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# 3D treatment planning system—Varian Eclipse for proton therapy planning

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ABSTRACT

The capabilities of the Eclipse treatment planning system (TPS) (Varian Medical Systems, Palo Alto, CA) for proton therapy treatment planning are described. Various steps involved in the planning process to produce a 3-dimensional (3D) dose distribution both for the passive scattering and pencil beam scanning proton beam therapy are outlined. Mitigation of range and setup uncertainties through robust optimization is discussed. Use of verification plans for patient treatment field dosimetry quality assurance (QA) is presented. Limitations of the Eclipse TPS and future developments are discussed.



## Introduction

The Eclipse treatment planning system (TPS) (Varian Medical Systems, Milpitas, CA) is widely used for proton therapy planning. The proton therapy treatment planning in Eclipse is built on the many features of the photon Eclipse TPS. The 3-dimensional (3D) images used for proton therapy treatment planning dose calculation are the same as those used for photons, namely computed tomography (CT) scans. Eclipse has the capabilities to do fusion of multimodality images, such as images from CT, positron emission tomography (PET), and magnetic resonance imaging (MRI), and to perform rigid and deformed image registration. It supports multimodality contouring. Many advanced tools for contouring of anatomical structures that are used for photon and electron therapy planning are also used in proton therapy planning. Both 2-dimensional (2D) and 3D viewing of the anatomical structures are also available. It has the capabilities to plan for the delivery systems currently used in the clinics, including double scattering or passively scattering proton beams, uniform scanning proton beam, and spot-scanned proton pencil beams. This review describes some of the special features of Eclipse TPS for proton therapy planning, namely (1) use of calibration curves for converting CT number to relative stopping power (RSP) of protons; (2) proton dose calculation algorithms; (3) incorporation of proton range and setup uncertainties in defining beam-specific planning targets; (4) planning for double or passive scattering and pencil beam scanning (PBS) proton beams; (5) plan evaluation tools; (6) plan transfer to electronic medical records (EMRs); and (7) tools available for providing planned dose for patient treatment field quality assurance (QA) checks.

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## Methods and Materials

### *TPS system*

Varian Eclipse TPS is used to plan for treatment for double scattering or passive scattering proton beams, uniform scanning proton beams, and spot-scanned proton pencil beams, as produced by widely used proton therapy delivery systems, namely Hitachi ProBeat system (Hitachi Ltd, Tokyo, Japan), IBA Proteus proton therapy machines (IBA International, Louvain-La-Neuve, Belgium), Varian ProBeam (Varian Medical Systems, Palo Alto, CA), Mevion proton therapy machines (Mevion Medical Systems, Littleton, MA), and others. The passive scattering or double scattering proton beam treatment involves the use of range modulator wheels to spread the pristine Bragg peak to a spread-out Bragg peak (SOBP) and 2 scatterers to spread beam in the lateral directions. In uniform scanning, the proton beam with constant fluence is spread laterally by magnetic scanning. The scanning proton beam uses magnetically scanned proton pencil beams or spots to produce broad fields or intensity-modulated proton beams for conformal proton therapy.

In all proton therapy TPS, images from 3D or 4-dimensional (4D) CT scans are used for dose calculation and display. The Eclipse TPS image registration workspace supports the fusion of other MRI or PET images with CT, and registration of various images for target and organ delineation and dose display in different image sets. Various advance features of contouring, such as auto contouring, expansion of contours, and Boolean operations, to create various planning target volumes are available in the contouring workspace. Various templates to name contours and assign certain contouring features such as colors are available for use as time-saving features. The image registration and contouring workspaces are same as those used for proton and electron beam therapy planning. For protons, the CT numbers or Hounsfield units (HU) need to be converted to the proton stopping powers relative to water. This is accomplished using a suitable HU to RSP calibration curve for each of the CT scanners used to acquire the images. Various procedures to create the calibration curve are described in the literature.[1,2] The effect of imaging artifacts near the high-Z materials on the accuracy of the calculated dose distribution is much more severe compared with photons, and a suitable override of the artifacts in the images is essential before proceeding for dose calculation. Additionally, the HU to RSP calibration curve may not be able to correctly predict the RSP of high-Z materials. They should be overridden with suitable HU or RSP. Eclipse TPS has the provision to override the HU or the RSP of any region of interest. A 3D CT image set and the contours for gross tumor volume (GTV), clinical target volume (CTV) and planning target volume (PTV) based on the magnitudes of setup and internal motion defined by the International Commission on Radiation Units and Measurements (ICRU) 62 and ICRU 78 reports,[3,4] and the organs at risk (OARs) are required before the treatment planning process can start. The PTV defined by the ICRU 62[3] for photons does not mitigate the range uncertainties of proton beams, as discussed later in this paper, but may be useful for design of apertures or to determine lateral margins for spot placements and plan evaluation for target coverage under geometrical (setup and internal organ motion) uncertainties only. The use of PTV for protons is discussed in ICRU 78.[4]

Like many other proton therapy TPS, the Varian Eclipse TPS uses proton pencil beam dose calculation algorithm[5,6] in which a broad incident beam is divided is divided into narrow pencil beams. The dose of the beam is calculated convolving the central axis depth dose of the beamlet, I(Z), with the lateral beam profile, K(r, ϕ, σ(z)). The dose is given by

$$D(r, \phi, z) = \Sigma I_p(z) \cdot K_p(r, \phi, \sigma(z)) \tag{1}$$

A Gaussian distribution with root mean square spread σ(z) is used to model the lateral distribution of the beamlet. The sum over p in Eq. (1) is carried over all the beamlets of the broad beam. The lateral beam spread parameter, σ(z), is obtained from the root mean square of lateral spread parameters due to various responsible scattering processes, namely multiple Coulomb scattering, large angle scattering, and nuclear interactions associated with proton beam interaction with the beam-modifying devices and media through which the beam passes. The Eclipse dose calculation algorithm is Proton Convolution Superposition. For the proton PBS beam, a double Gaussian model is used to represent the spot profiles and provides a better agreement between the calculated and the measured dose distribution for the broad beams created by the superposition of proton pencil beams. A Monte Carlo simulation-based dose calculation algorithm option is also available in the latest version of the Eclipse TPS, but its use in the clinical treatment planning remains limited. Details of passive scattering proton beam and scanning beam field shaping, and dose calculation algorithms are available in the literature[7-9] and are not repeated in this paper.

### *Planning for the treatment with passive scattering proton beam therapy*

In the passive scattering proton beam therapy, the crossplane or lateral dose conformity around the target is achieved by using the customized apertures, and longitudinal dose conformity is achieved by the selection of appropriate range of the proton beam and customized compensators and beam modulation width. The treatment planning for the passively scattering proton beam involves the following steps.