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Development of GUI-Based BNCT Treatment Planning System

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1. Introduction

In previous study, BNCT Treatment Planning System (BTPS), which can generate a voxel phantom from patient's images and analyze absorbed dose based on dose calculation using MCNP, had been developed at Hanyang University [1]. The previous BTPS should require pre/post processing programs to automatically generate a MCNP input for whole treatment environments and to automatically import results from MCNP run [2].

In this study, the previous BTPS has been improved to facilitate treatment planning for BNCT through the use of a friendly graphical user interfaces (GUI) and a fully automatic process associated with MCNP.

2. Methods and Materials

Overall procedures of the BTPS were re-designed according to clinical treatments of BNCT. The process of practical BNCT consists of planning, treatment, and posterior estimation in irradiation. In the planning, a plan with treatment environments can be set up. And, in the posterior estimation, optimized irradiation time can be immediately provided by re-calculating the absorbed dose with measured data, including boron concentrations in normal/tumor tissue and irradiating neutron flux.

A GUI based BTPS was built with C++ Builder, and works on the Windows® platform. The BTPS includes three common modules and a dose calculation engine. The three main modules, image, plan, and analysis module, are systematically linked to MCNP by the dose calculation engine. The MCNP input of a treatment plan is automatically generated, and a result from the MCNP run is also automatically exported to the analysis module by the dose calculation engine. The planning and analysis of BNCT treatment using the BTPS is facilitated.

3. Results

In this section, features of each module are briefly described.

3.1 Image Module

The image module visualizes all procedures of a treatment plan using the BTPS. The image module supports DICOM, the standard medical imaging format. Especially, the patient-specific 3D voxel phantom from patient's images is reconstructed for planning BNCT. The interface of the image module is shown in Figure 1.

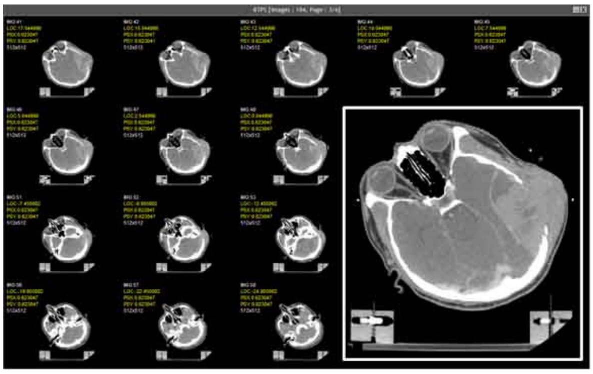
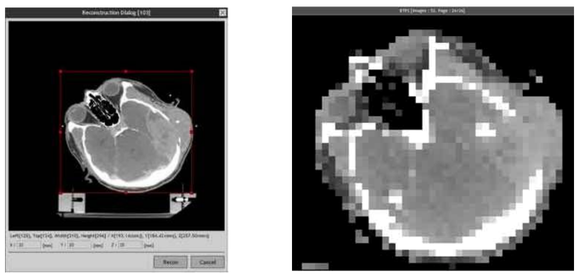


Figure 1. A Screen Shot of the Image Modules: An Image Set of a Patient with Glioblastoma Multiforme

A 3D voxel phantom is generated with manual definition of Region-Of-Interest (ROI) and voxel size, as shown in Figure 2. Each voxel is classified into three primary materials, such as air, normal tissue, and bone, based on average CT number in each voxel [3]. The data of the 3D voxel phantom are exported to the dose calculation engine.

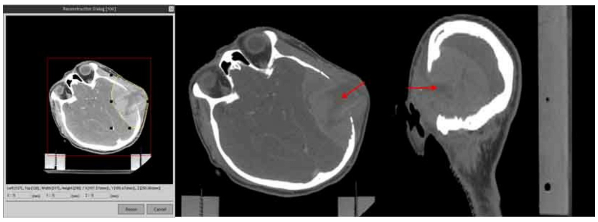


(a) Definition of ROI (b) A Generated Voxel Phantom

Figure 2. A Screen Shot of the Image Module: Making a Voxel Phantom

3.2 Plan Module

The plan module simulates all treatment environments for BNCT. Gross Tumor Volume (GTV) is delineated, and position and direction of an irradiation field are created with easy manipulation, as shown in Figure 3. Energy spectrum and radial/angular distribution of the field can be easily adjusted by using a conventional editing program. Boron concentrations, in voxels of tumor or normal tissue, are inserted for dose calculation.



(a) Delineating GTV (b) Creating an Irradiation Field
Figure 3. A Screen Shot of the Plan Module: Planning Treatment Environments

For dose calculation based on MCNP, tally types of dose components or neutron fluxes are selected. Because four dose components, such as boron, neutron, proton, and gamma doses, are mainly contributed to absorbed dose in BNCT, the four dose components are basically selected. And to decrease computation time for calculating the neutron fluxes in the phantom, the neutron fluxes can be optionally selected. Mesh tally or lattice tally, which are tools in MCNP, are used selectively for dose calculation. The data of the treatment environments are exported to the dose calculation engine.

3.3 Dose Calculation Engine

The dose calculation engine contains several methods for generating MCNP input and analyzing results from MCNP run. A 3D voxel phantom from the image module and the treatment environments from the plan module are consolidated and converted to MCNP input. Selected dose components or fluxes are calculated using kerma values corresponding to each dose component.

The dose calculation engine imports the results from the MCNP run, and calculates the four dose components [Gy-Eq/incident neutron] with RBEs and CBE. The absorbed dose [Gy-Eq/incident neutron] is calculated by combining the four dose components and boron concentrations, as follows:

$$D^{(i,j,k)} = RBE_n \times D_n^{(i,j,k)} + RBE_p \times D_p^{(i,j,k)} + RBE_\gamma \times D_\gamma^{(i,j,k)} + B.C_B^{(i,j,k)} \times CBE_B \times D_B^{(i,j,k)}$$

where

(i, j, k) = Voxel Indexes of x, y, z direction

D_n, D_p, D_γ, and D_B = Neutron, Proton, Gamma, and Boron Doses

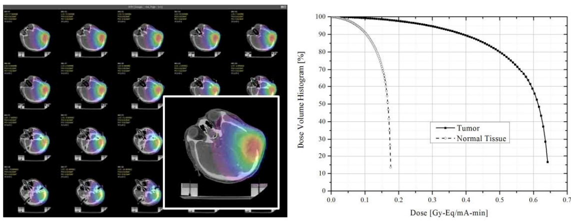
RBE_n, RBE_p, RBE_γ, and CBE_B = Relative Biological Effectiveness and Compound Biological Effectiveness

$B.C_B^{(i,j,k)}$ = Boron Concentrations in $Voxel^{(i,j,k)}$

Since various tools, including mesh tally and parallel computing system, are employed in dose calculation using MCNP, computation time is decreased to be under a few minutes [2]. The absorbed dose from the treatment plan can be immediately re-calculated with measured boron concentrations from monitoring systems.

3.4 Analysis Module

Functions of the analysis module are reporting and analyzing BNCT for evaluating a treatment plan. The analysis module imports all doses or neutron fluxes from the dose calculation engine. And total doses or neutron fluxes are calculated with neutron flux of irradiation beam and treatment time in BNCT. The total doses or neutron fluxes are converted and displayed to be isodose contour or Dose Volume Histogram (DVH), as shown in Figure 4.



(a) Isodose Contour (b) DVH
Figure 4. A Screen Shot of the Analysis Module: Displaying Total Doses

4. Conclusion

The BTPS facilitates treatment planning for BNCT based on dose calculation using MCNP. The BTPS enables patient-specific treatment environments for BNCT to be easily planned and absorbed dose or neutron fluxes also to be calculated and analyzed through a friendly GUI, as a fully automatic process associated with MCNP. It is expected that the BTPS can be directly applied to clinical treatments of BNCT.

Acknowledgement

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