CHEN-1: Design of a BNCT treatment planning system and its considerations - The development of NeuboronPlan

Jiang Chen[1], Ian Postuma[2], Wei-Lin Chen[1], Silva Botorlussi[2], Diyun Shu[1,3], Yuan-Hao Liu[1,3]
[1]*Neuboron Medtech Ltd., Nanjing, Jiangsu Province, P.R. China*
[2]*Istituto Nazionale Di Fisica Nucleare (INFN), Unit of Pavia, Italy*
[3]*Nanjing University of Aeronautics and Astronautics, Nanjing, Jiangsu Province, P.R. China*

The treatment planning system (TPS) for BNCT has many common considerations same as the TPS for conventional radiotherapy, while there are still different ones. The NeuboronPlan, a TPS for BNCT, was developed for the need of high precision dose calculation. From its development, we have found the following vital features of a good BNCT TPS; the design considerations and recommendations are given as follows.

1. Medical Image

A BNCT TPS must be able to process CT images, and it should support the DICOM-RT format in order to provide a compatibility to the conventional TPS. A further feature is a support of PET and MRI images, which is not yet a mandatory requirement, but it is favorable; the CT/PET image fusion provides valuable information of in-vivo boron distribution, which can further assign boron concentration data to voxel cells.

2. Material Conversion

Unlike the photon radiotherapy, the dose calculation in BNCT requires the transportation calculations for not only photons, but also neutrons, which needs a detailed description of materials presented in the calculation. The materials of interest should be converted directly from the anatomy image, saying CT images, with a reliable and trustworthy mechanism. The recommended method is converting the Hounsfield unit values of CT images into corresponding materials and densities. The use of a simplified material table is not recommended.

3. Voxelization

In the past two decades, the BNCT TPSs used the so-called homogenized model to reduce the number of generated voxels; a huge number of voxels may cause a crash of the TPS, or lead to a very long calculation time. However, the homogenization could lead to a reduction of spatial resolution, as well as a loss of material information. It is recommended to use a point-to-point conversion and built a voxelized phantom truly from the CT images, without a sacrifice of accuracy. Voxel number is no longer a bottleneck of modern computer system.

4. Monte Carlo code and Cross-section Library

BNCT dose calculation relies on the use of Monte Carlo method, in order to transport neutrons and photons amid the region of interest and obtain the corresponding doses. Currently, the most recognized and applied MC codes are the MCNP (version later than MCNP5 v.1.51) and PHITS (version later than v.2.24), which can successfully transport both neutron and photon. The dose calculation should be performed basing on a creditable and continuous-energy cross-section library, which should be clearly stated in the TPS report. A library newer than ENDF/B-VII.0 or JENDL-4.0 is recommended. Due to the group-wised neutron energy in transportation, the MC code FLUKA is not recommended. Other MC codes that can transport neutrons and photons reliably and satisfy the aforesaid issues can also be used; GEANT4 is one good example.

5. Dose Calculation

Both neutron and gamma ray have to be calculated; for neutron part, the secondary gamma-ray must be included in the transportation as well. The neutron physical dose should be calculated basing on the heating number of each element; for the photon one, KERMA factor (or F6 tally in MCNP) is preferable to save time (without electron transportation). The calculated physical dose has to be further interpreted into radiobiological weighted dose by using a library of RBE and CBE factors; an alternative option is the use of radiobiological weighting function, e.g. a photon iso-effective dose deriving equation, to replace the RBE and CBE factors

The developed TPS must also comply with the IEC 62083-2009 requirement, or similar standard. More details will be presented in the full report and our presentation