Beam shaping assembly optimization by maximizing the uncomplicated tumor control probability on a cylindrical phantom.

I. Postuma[1], L. Provenzano[2,3], S. Bortolussi[1,4], N. Protti[1], S. Fatemi[1], C. Magni[1,4], C. Gong [1],

and S.J. González[2,3]

[1] Istituto Nazionale di Fisica Nucleare (INFN), Unit of Pavia, via Bassi 6, (27100) Pavia, Italy.
[2] Comisión Nacional de Energía Atómica (CNEA), Av. Gral Paz 1499 (1650), San Martín, Buenos Aires, Argentina;
[3] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Godoy Cruz 2290 (1425), Argentina;
[4] Department of Physics, University of Pavia, via Bassi 6, (27100) Pavia, Italy;

E-mail: ian.postuma@pv.infn.it

The development of a clinical performing beam for Boron Neutron Capture Therapy (BNCT) is a complex task. The Beam Shaping Assembly (BSA) material composition and geometry has to be tailored on the initial neutron source which can be a nuclear reactor or a charged particle accelerator, with the latter having become recently available. Hence, several technologies have been developed, each one having its own accelerator characteristics, target and BSA. As a result, every neutron beam has distinct features for neutron spectra, photon contamination and lateral radiation leakage.

Neutron beams are compared through figures of merit (FOM) proposed in the BNCT technical document by IAEA in 2001, these FOMs describe beam intensity, contamination by fast neutrons and gamma rays, and divergence of the beam. In the last years it has been evidenced these FOMs are not exhaustive for the characterization or comparison of BSAs [1, I. Postuma to be published]. To better judge the performance of a neutron beam, more sophisticated tools based on voxelized phantoms are being developed [L. Provenzano to be published]. A more refined procedure is to perform a BNCT treatment simulation to evaluate clinically relevant parameters such as the Uncomplicated Tumor Control Probability (UTCP) [L. Provenzano, to be published]. This single scalar value condenses 3D information of dose distribution that, in turn, influences the treatment, both about tumour control and about normal tissues side effects. Consequently, evaluating the UTCP on a standard phantom may be a consistent way of comparing neutron beams for BNCT. Moreover, it is increasingly evident that the clinical evaluation with equivalent dose is not representative of the outcome of BNCT trials. Therefore, UTCP is evaluated from the absorbed dose by using a radiobiological model that equals TCP and NTCP of mixed field radiation to photons.

Concerning recent developments of accelerators to be used in BNCT, the Italian National Institute of Nuclear Physics (INFN) has built a 5 MeV RFQ proton accelerator with a current of 30 mA. This machine if coupled to a beryllium target is capable of delivering 10^{14} neutrons per second. It has been demonstrated that it is possible to tailor a clinically performing epithermal neutron beam for this machine, with a BSA where the bulk material is composed by AlF_3 and Li.

In this work, the UTCP has been used to guide improvements in the design of the aforementioned BSA by maximizing its value. The work that will be shown is performed by simulating by MCNP6 the initial neutron spectra on the beryllium target, using measured data [2]. The geometrical model of the cylindrical phantom used for MC simulations and estimations of the UTCP was generated with MultiCell, and coincides that used by Provenzano et al work. IAEA FOMs were computed, as a reference, by averaging the tallies over the beam port. Finally, it will be shown how the UTCP was able to guide the final tailoring of the BSA and dosimetry in the peripheral body of the patient will be compared with the previous version of the projected beam.

References

1. Herrera, M. S., et al. "Evaluation of performance of an accelerator-based BNCT facility for the treatment of different tumor targets." *Physica Medica* 29.5 (2013): 436-446.
2. Agosteo, S., et al. "Characterization of the energy distribution of neutrons generated by 5 MeV protons on a thick beryllium target at different emission angles. "*Applied Radiation and Isotopes*" 69.12 (2011): 1664-1667.