Development of a 3-dimension scintillation dosimeter for small irradiation fields control in pencil beam scanning proton therapy

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Résumé

Introduction: In proton therapy, the treatment of tumors smaller than 3 cm is limited by the uncertainties of the treatment planning system and the spatial resolution of control detectors (Clausen,2023). Moreover, with the pencil beam scanning (PBS) technique, the treatment plan is structured as a sum of pencil beams (PB), each delivered in several pulses of variable intensity also called bursts (blind golfer algorithm).

Material and Methods: To answer these issues, we developed a high spatial and temporal resolution dosimeter called SciCoPro to control treatment plans. This dosimeter is based on a cubic plastic scintillator of 10x10x10 cm3 and a fast camera capable of reaching 1 kHz (the beam delivery frequency). A mirror allows seeing two views of the scintillator. The setup can record each delivered burst and reconstruct pencil beams' characteristics (energy, position and intensity). An algorithm was developed to calculate the dose distribution from SciCoPro's acquisitions. By retro-projecting both views of the cube in the 3D space, the algorithm reconstructs the scintillation map before converting it into dose distribution. The algorithm can reconstruct the scintillation map thanks to the radial structure of PBs. Several optical corrections, such as vignetting, inner reflections and scintillator's attenuation, are currently being implemented to correct optical biases.

Results: The system's performances were assessed with customized irradiations and with clinical treatment plans. The setup was proved to be able to measure the characteristics of each delivered burst for intensities as low as 0.002 Monitor Units (MU) and showed uncertainties below 580 μm for the PBs position, 3 % for the intensity (in MU) and 180 keV for the energy (Frelin, 2024). The dose distribution reconstruction is currently under finalization and evaluation. Preliminary results were obtained for a customized irradiation plan delivering a homogeneous dose of 0.8 Gy in a sphere of 5 cm diameter. Dose profiles taken in the X, Y and Z directions showed a good shape agreement with the ones provided with the TPS. Moreover, preliminary mean discrepancies in the 80% dose area have been evaluated at (1.8

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± 2.8) %. This result can be explained by the incomplete biases corrections (still ongoing), which need to be improved to fulfill dosimetry accuracy requirements and for conducting further analysis.

Conclusions: We developed a very promising scintillation dosimeter adapted to PBS and blind golfer delivery strategy, able to control the characteristics of all the PBs of a treatment in a single irradiation measurement. The associated 3D-reconstruction algorithm has provided preliminary results in agreement with TPS dose distributions. Optical corrections are being implemented to improve the dose accuracy. In the medium term, SciCoPro will be a very valuable tool to verify 3D dose distributions in small field irradiations.

References:

- Monika Clausen, Sirinya Ruangchan, Arame Sotoudegan, Andreas F. Resch, Barbara Knäusl, Hugo Palmans, Dietmar Georg, Small field proton irradiation for in vivo studies: Potential and limitations when adapting clinical infrastructure, Zeitschrift für Medizinische Physik,2023, Frelin AM, Daviau G, Bui MHH, et al. Development of a three-dimensional scintillation detector for pencil beam verification in proton therapy patient-specific quality assurance. *Med Phys.* 2024; 51: 9318–9329. https://doi.org/10.1002/mp.17388

Mots-Clés: protonthérapie, PBS, scintillateur 3D, reconstruction 3D