Contribution ID: **89** Type: **Talk**

First online image-guided treatment of a murine tumor with radioactive ion beams

Keywords: carbon ions radiation therapy, beam range verification, PET, radioactive ion beams

Charged particle therapy is a well-established and effective clinical practice, given the advantages in the dose deposition during the treatment when compared with conventional X-rays radiotherapy. On the other hand, a major drawback is the range uncertainty in dose delivery, which jeopardizes the advantages of the sharp Bragg peak. By using radioactive ß+-emitting ions coupled with positron emission tomography (PET) imaging, enabling reliable online beam monitoring, the tumor margins could be reduced, allowing better sparing of healthy tissue.
In the context of the BARB experimental campaign held at GSI, we performed the first treatment of a murine tumor using radioactive ion 11C beams coupled with online PET image-guidance. C3H/HeNRj mice bearing a syngeneic LM8 osteosarcoma above the cervical spinal cord, which irradiated with 209 MeV/u 11C ions and a dose of 20 Gy. The activity induced in the animals was monitored online by means of the SIRMIO PET detector (Prof. Parodi's group, LMU, Münich) leading to the possibility of monitoring the particle range online - by first shooting a 1 Gy 'probe'pencil beam to check the beam position in the mice bodies, and delivering the rest of the dose just afterwards based on the measured activity. To confirm the match between planned dose distribution, measured activity and the biological outcomes, three different treatment groups were used, to monitor tumor control and healthy tissue side effects. The organs at risk in this experiment are the esophagus and the spinal cord, damage to which leads to radiation-induced side effects like dysphagia, weight loss, inflammation and myelopathy, respectively. The mice were monitored for six months post irradiation and were subjected to health check-ups and motor efficiency tests, followed by histological analysis.
We observed side effects and tumor growth trends correlated with the activity observed in the animals, i.e. in the mice, where the observed range was too short, we have not reached tumor control, and in the mice where the peak of measured activity was deeper than expected, we observed tumor control, but also stronger esophageal toxicity. In the case of the activity measured in the expected position, instead, we reached tumor control and spared the healthy tissues. These results demonstrate the feasibility of simultaneous treatment and image-guidance in charged particle therapy by means of using radioactive ion beams and paving the way for future clinical applications.
The experiment was supported by the ERC AdG 883425 to Prof. M. Durante (https://www.gsi.de/work/forschung/biophysik/erc_barb).

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Session Classification: Parallel: Life (RT3)

Track Classification: RT3