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Laser optical feedback imaging in quantitative experimental 3D polymer gel dosimetry studies for synchrotron stereotactic radiotherapy.

Purpose:

The Synchrotron Stereotactic Radiotherapy (SSRT) is a binary cancer treatment modality that involves the selective accumulation in tumors of a high Z element and a kilovoltage x-ray irradiation with a sufficient beam intensity (as achievable with a synchrotron beam source). The attending effect is a dose enhancement in the tumor due to the secondary particules generated by photoelectric interaction. The theoretical dosimetry of this radiation therapy modality is based on Monte Carlo simulations, which is the only reliable technique, because of the increased heterogeneity in materials and interactions occurring compared to conventional high energy photon external beam radiotherapy. The experimental dosimetry is then performed with ion chambers for punctual measurements, gafchromic films for 2D relative dose mapping (refs Morris) and normoxic polymer gel (nPAG) dosimetry for 3D experimental gel dosimetry [Boudou2005]. The difficulties in using 3D polymer gels is the capacities of the imaging tools in terms of spatial resolution, reproducibility for quantitative measurements (need of re-calibrations), high acquisition times, and limited access to the devices. This context suggests the development of other imaging tools as optical devices to improve the 3D dosimetry. We evaluated a promising optical imaging technique for retrieving 3D quantitative dose maps, the Laser Optical Feedback Imaging (LOFI). We irradiated phantoms in SSRT mode using the synchrotron x-rays from the ESRF medical beamline and characterized the phantoms (LOFI) in terms of sensitivity, spatial resolution, accuracy, precision, acquisition time and ability to assess the dose enhancement.

Materials and methods

Irradiations were performed at 50 keV, which is the theoretical optimal energy for obtaining the maximum dose enhancement.

We used 3D nPAG gel polymer and studied the following irradiation parameters:

1) Dose of irradiation (0 to 8 Gy) in gels containing or not iodinated contrast agent
2) Size of the irradiated zone sub-millimetric to centimetric (from 100 microns to 1 cm)

3) High dose gradients, such as in a real SSRT treatment.

Results

The characteristics of MRI imaging tools (a 3T magnetic resonance imaging scanner, Brucker Biospin® , Germany) were determined by calculating the transverse relaxation rates (R2) in each pixels of the images. This study was performed in collaboration with the MR unit at the Grenoble-CHU (Dir: JF Le Bas, Research Engineers: I Troprès, L Lamalle). The linearity between R2 and the dose was checked for normal gels and doped gel with 10 mg/mL of iodine (cf figure). A linear relationship was obtained for the normal gels (up to 8 Gy), and up to about 5 Gy for doped gels, where we observed saturation.

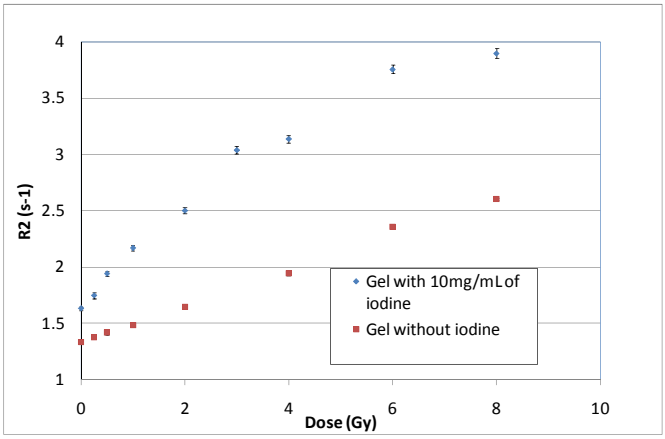

Figure: Relationship between transverse relaxation rates (R2) and the dose delivered to normal and doped gels with 10mg/mL of iodine (Iomeron).

The comparison with the LOFI technique is not fully completed due to a technical problem with the instrumentation. Different strategies to overcome this problem are under study.

Conclusion

High spatial resolution 3D dosimetry remains an active area of research in complex radiotherapy techniques such as IMRT. The LOFI technique needs to be improved for imaging large samples as those used in dosimetry for radiotherapy.

[Boudou2005] Boudou C, Balosso J, Esteve F and Elleaume H. Monte Carlo dosimetry for synchrotron stereotactic radiotherapy of brain tumours. Phys. Med. Biol. 2005;50:4841:4851.