Microenvironment adapted treatment planning for ion beams*

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Internally heterogeneous tumors are strongly correlating with poor prognosis. One of the principal source of biological intra-tumour heterogeneity is the local microenvironment, e.g. the condition of oxygenation verified in different tumor regions, or the concentration of a given radiosensitizer presenting a differential uptake within the malignant tissue.

With particle therapy is now possible to exploit the ion beams radiobiological advantages for targeting the most resistant cells, and through the flexibility of active beam scanning, creating specific adaptive treatment plans [1-4].

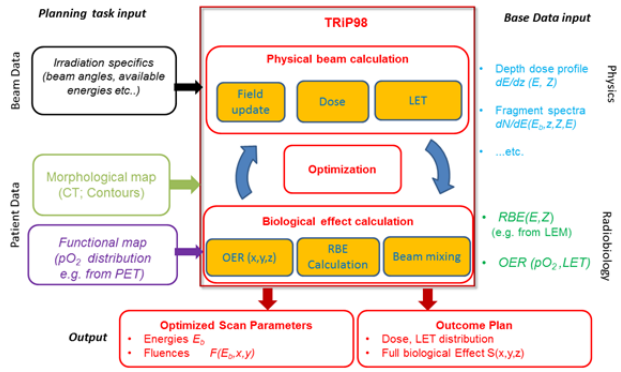

Figure 1: Present structure of TRiP98 code, including the adaptive implementation, which allows processing functional information of the tumor, beside morphology.

Exploiting different ion beams

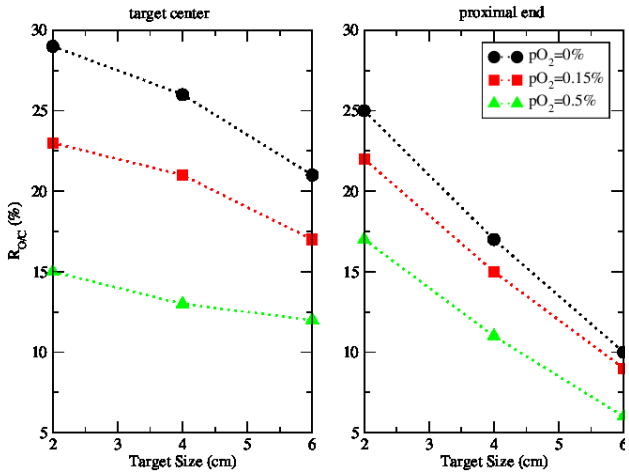

Figure 2: Relative reduction ($R_{O/C}$) of the oxygen enhancement ratio in an hypoxic target by using an oxygen beam with respect to carbon, for different position within the target, size and different level of hypoxia (pO_2).

In this connection, beside the possibilities of plans with carbon ions, which are the established particles in use in the modern facilities, higher LET ions like oxygen-16, offer the opportunity of targeting even more efficiently the regions of increased resistance, e.g. in the case of hypoxia. An example is shown in figure 2. The combination of different ion peculiarities [3] is even more promising.

Experimental verification

The adaptive treatments plans have been verified in several irradiations performed at GSI and NIRS (Japan).

To this aim, specific bio-phantoms composed by cell holders at different conditions were prepared (Figure 2).

The results have been recently submitted [4], showing a remarkable agreement.

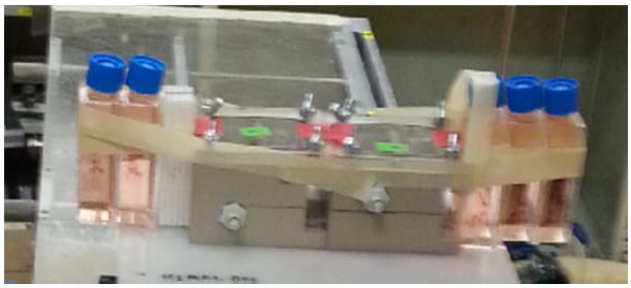

Figure 3: Example of experimental device used for verification of microenvironment adapted treatment planning: biological phantom composed by normoxic cells (tissue culture flasks) and cells at different oxygenation conditions (hypoxic chambers).

References

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[4] W. Tinganelli, M. Durante, R. Hirayama, M. Krämer, A. Maier, Y. Furusawa, W. Kraft-Weyrather, and E. Scifoni, “Kill-painting of hypoxic tumors with charged particle therapy”, Sci. Transl. Med., submitted (2015)

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