MRT-planning (similarities and differences with and between planning for therapy with photons, hadrons and MR)

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Rationale and objectives

Using established radiosurgical techniques, acute and delayed radiobiological responses of tissues are predictably dependent on the quality, the rate, and the density of ionisation energy imparted to them (i.e., radiation 'doses' and 'dose' rates). Although different kinds of tissue display various early and late responses to a given irradiation, whether the imparted dose be uniform or not, normal tissue reactions are predicted reliably for clinical radio-oncology by analysing overlays of dose distributions on serial tomographic images of the irradiated volume.

Treatment planning for MRT will be more complex. Microscopically contiguous cells in the same tissue may be exposed to drastically different doses. Unfamiliar tissue responses may be elicited by various microscopic dose distributions, depending on the organization of the tissue, its milieu intérieur, and its microvasculature. It is natural that we concentrate on the most obvious factors first. Radiation dose-response curves for cells grown in vitro have yielded relative biological effectivenesses (RBEs) applicable to broad-beam radiation therapies, including hadron and pion therapy. Since microscopically contiguous cells in the same tissue may be exposed to drastically different doses from microbeams, RBE data for MRT are needed more for vascularized normal vital animal tissues in vivo than for colonies of non-vascularized cells in vitro.

Established treatment planning systems have to be checked on a regular basis by physical dosimetry. This is done in homogeneous phantoms, preferably with calibrated ionization chambers. While this technique is well established for photon, electron and proton irradiations, for hadron therapy absolute calibration, demanding and imprecise, remains elusive. For MRT, dose calibration is even more difficult, as precise physical microdosimetry is still under development. Even Monte-Carlo (MC) dose computations (1), so far the method of choice for MRT, should be provided with large error bars. Accordingly, an MRT treatment planning program for large animals will be developed in an iterative process.

Methods

The most important single parameter responsible for tissue response to microbeams is believed to be the ‘valley’ dose. The valley dose will be calculated by MC calculation for microbeam exposures in a geometrical phantom, built up by solid tissue substitutes. The resulting dose distribution will be measured with radio-chromic films and at some

locations with ionization chambers, to establish the relationship between calculated and measured dose.
For treatment of animal patients the valley dose is calculated in a simplified geometry, but taking into account volumes of significantly higher or lower x-ray absorption as bone or air. The calculated doses will be checked in a parallel plate phantom setup imitating the volume to be irradiated.
If the starting dose for the dose escalation program is selected conservatively normal tissue damage will be avoided.

Results / Conclusion

The proposed course of action aims at making full use of the existing results from rodent and pig irradiations (2,3) and at the same time moving from the predominantly used exposures of around 28 µm beam width and 200 µm beam separation of small irradiation volumes to 50 µm beam width and 400 µm separation in significantly larger volumes.

References

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