Systematic investigation of RBE using the particle irradiation data ensemble*

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Introduction

Survival assays of cultured cells are frequently used to investigate the response to both photon and ion radiation. Its dose dependence is commonly visualized as survival curves. An enhanced efficacy of ion irradiation compared to photon irradiation is evident for many endpoints and is expressed by the relative biological effectiveness (RBE), which is the ratio of doses of ion and photon radiation needed to cause the same effect [1]. The experimental investigation of the systematics of RBE and dose response curves is complemented by predictive models such as the Local Effect Model (LEM). To probe their accuracy a global view on available data is needed. Therefore the Particle Irradiation Data Ensemble (PIDE) was set up [2], which is a collection of ion and photon survival curves from the literature. Meanwhile it comprises 855 dose response experiments, parameterized by the linear-quadratic (LQ) model for photons and ions, from 77 publications [3].

Results

For ion irradiation survival decreases usually linearly with increasing dose. This makes it difficult to perform reliable fits in particular for the quadratic parameter β_I. It is not clear up to now how β_I evolves with LET. Here PIDE allows model comparisons with good statistics.

Figure 1 presents β_I normalized to the photon β_γ parameter vs LET for different particle types and cell lines. The spread of the data points is large, and it is unclear if β_I systematically exceeds β_γ or falls off starting from small LET. Hence a running average procedure was applied. The emerging average curves suggest a small initial increase of β_I and a final falloff to zero. It may be explained by saturation effects, as for very large LET each hit cell is killed anyway, and hence only hit statistics matters, resulting in a straight survival curve.

Experimental findings do not precisely reveal the nature of β_I, and also RBE models reflect a huge variability in the predictions. This can be seen in Fig. 2 where β_I for three models is compared with data from two cell lines. The figure indicates that neither experimental nor model data show a clear systematics, so some aspects of high LET cell survival are still unclear. With respect to clinical applications the accurate modelling of β_I presumably becomes relevant in hypofractionation, whereas for more conventional fractionation schemes treatment plans are comparably robust against larger variation of β_I.

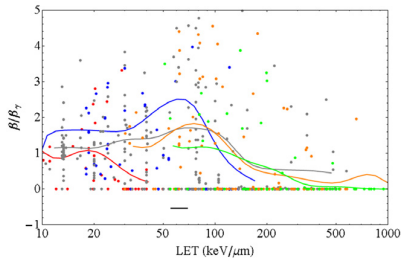

Figure 1: Ratio of the LQ parameter β_I of ions to that of photons vs LET for monoenergetic ions for different ion species (p: red; He: blue; C: grey; Ne: orange; heavier ions than Ne: green). The solid lines are running averages with correlation length as indicated by the horizontal bar.

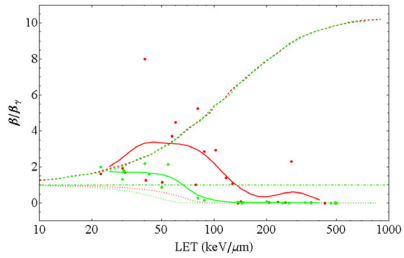

Figure 2: As Fig. 1 for two individual cell lines (V79: red, HSG: green). Thick lines: running averages of the data. Dashed, dotted and dashed-dotted lines: model predictions of the repair-misrepair-fixation model, the LEM, and the microdosimetric-kinetic model, respectively.

Conclusions

The presented example demonstrates that the PIDE is appropriate to identify open points in the dose response systematics. It is helpful for model evaluation and accessible to the research community (http://www.gsi.de/bio-pide).

References

[1] ICRP Report 92, Elsevier (2003).
[2] T. Friedrich, GSI Sci.-Rep. 2010, Health-22.
[3] T. Friedrich et al., J Radiat Res 2012, in press.

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