Teaching Lecture: Dose to water vs. dose to tissue in advanced treatment planning: myths, realities and concerns

SP-0388
Dose to water vs. dose to tissue in advanced treatment planning: myths, realities and concerns

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Teaching Lecture: Nanodosimetry: from radiation physics to radiation biology

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Nanodosimetry: from radiation physics to radiation biology

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Nanodosimetry is an emerging experimental technique that measures the so-called particle track structure, i.e. the pattern of ionizing radiation interaction with matter on the nanometric scale. In such small dimensions, comparable to the diameter of the DNA double helix, the stochastic nature of ionizing radiation interactions has to be taken into account.

The stochastic quantity of nanodosimetry is the ionization cluster size (ICS), i.e. the number of ionizations produced by a passing particle within a specific nanometric target volume. The frequency distribution of ionization cluster size (ICSD) depends on the size of the target volume and its distance from the primary particle trajectory. The ICSD is a characteristic of the track structure. The statistical moments of the ICSD can be used to establish a new concept of radiation quality that is based on measurable physical quantities of the radiation that are closely related to the biological effects of the radiation.

Three nanodosimeters of different type have been developed for measurement of ICSDs [1-3] in a sensitive volume of a dilute gas which is simulating microscopic targets based on a density scaling principle [4]. They are differing in the operating gas used, the detected particle type (electrons or cations of the target gas) and the size of the equivalent nanometric target in biological matter (a.k.a. site size). Within the European Project BioQuaRT [5, 6] and the adoint Italian MITRA project [7], the three European nanodosimeters (“StarTrack”, “Ion Counter”, “Jet Counter”) [8-10] have been compared by measuring ion beams with all three nanodosimeters.

Fig. 1 shows a synopsis of particular moments of all measured ICSDs. Each data point represents a measurement of a radiation quality (energy and type of ion) with a particular nanodosimeter simulating a certain nanometric site size. The horizontal axis is the mean ionization cluster size M1(Q), i.e. the number of ionizations obtained for the combination (indicated by Q) of radiation quality and site size. The vertical axis is the cumulative probability F2(Q) for obtaining at least two ionizations when measuring this radiation quality with the respective nanodosimeter. These quantities are obtained from the measured frequency P(ν|Q) of ionization cluster size ν.

Fig. 1
All data points shown in the Fig. 1 are falling on the same curve indicated by the dashed line. Similar results are also found when cumulative probabilities Fk for a cluster size ν ≥ k are plotted versus M1. Hence, despite the different operating principles of the nanodosimeters, there seems to be a universal relation between the cumulative probabilities Fk and the mean ionisation cluster size M1.

The saturation behavior seen in Fig. 1 is found for all cumulative probabilities Fk. Hence, the universal curves have a similarity to the curves expected for the yields of radiobiological endpoints. Fig. 2 illustrates, that this similarity can be exploited to establish a quantitative correlation between nanodosimetric quantities and radiobiological effects.

Fig. 2
The colored data points are results from cell experiments using protons (blue) and carbon ions (red). The vertical axis is the cross section for cell inactivation determined from the cell survival curves at 5% survival rate [11, 12]. The horizontal axis is the mean ionization cluster size that was obtained from Monte Carlo simulations. The black data points are mean cluster size and cumulative probability F2 derived from the simulated ICSDs.

The track structure simulations were carried out for different values of the nanometric site size. The data plotted in Fig. 2 are those for which the nanodosimetric curve indicated by the grey line provides a best fit to the radiobiological data. This best fit is obtained if a site size of 1 nm in liquid water is used, i.e. of about half the diameter of the DNA double helix.

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Teaching Lecture: Brachytherapy for the pelvic region: status and perspective for the future

SP-0390
Brachytherapy for the pelvic region: status and perspectives for the future - Gynaecology
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Brachytherapy in gynaecological cancers, and especially in cervix cancer, has greatly evolved during the last twenty years. For decades, brachytherapy has relied on x-ray orthogonal acquisitions, and prescription has been a matter of systems and schools, making reporting and comparisons difficult. Based on the developments of afterloaders and treatment planning systems, image-guided adaptive brachytherapy has emerged. This high precision technique combines all modern radiation requirements: image guidance, adaptation to tumor response, and short time treatment. Ten years ago, the GEC-ESTRO, in a wish of harmonizing practices, published recommendations in cervical cancers regarding the definition of target-volumes and the reporting. These recommendations were rapidly adopted worldwide. During the last decade, multiple monocentric series, historical cohorts’ comparisons, and a prospective multicentric study (STIC trial) demonstrated high local control rates with a limited morbidity in regard to classical data. These data are about to be confirmed by two large prospective monocentric studies led by the Gyn GEC-ESTRO: Retro-EMBRACE and EMBRACE, which will establish MRI-guided brachytherapy as a gold standard.

In addition, clear dose-volume effect relationships have been demonstrated between the modern dosimetric parameters and the probability of achieving local control or facing morbidity. The better knowledge of these correlations allowed the launch of EMBRACE II, a prospective study combing the best radiation modalities (EBRT and IGBT), with optimal and ambitious planning aims. In the near future, the large amount of data collected in the EMBRACE study (> 1 500 patients accrued) will allow the development of monograms integrating not only dosimetric parameters, but also criteria on comorbidities, clinical features, and tumor response to external beam radiotherapy. This would be of great help in adapting and personalizing treatment plans. Longer-term prospects include the development of alternative image modalities for guidance, such as endorectal ultrasound, cheaper and more accessible than MRI, or conversely, a more advanced and sophisticated image modality. Image-guided brachytherapy is also progressively declined in other gynecological tumors, such as vagina cancer or non-operative endometrial cancer.

SP-0391
Brachytherapy for the pelvic region: status and perspective for the future - prostate
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Prostate brachytherapy allows radiation dose escalation directly into the gland with minimal dose to adjacent rectum and bladder. Over the last decade improvements in brachytherapy technology have refined dose delivery with the introduction of HDR after loading devices, more sophisticated treatment planning systems and the incorporation of functional imaging into the planning process. This teaching lecture will provide an overview of the techniques, indications, and clinical outcomes for both permanent and High Dose Rate prostate brachytherapy. Recent results from randomised clinical trials will be critiqued and emerging indications including focal and salvage treatments discussed.

Symposium with Proffered Papers: Adaptive radiotherapy for coping with anatomical variations: hope or hype?

SP-0392
Overview of clinical practice of ART for pelvic tumours
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Introduction: Variation in shape, position and treatment response of both tumour and organs at risk are major challenges for accurate dose delivery in radiotherapy. Adaptive radiotherapy (ART) has been proposed to customise the treatment to these motion/response patterns of the individual patients, but increases workload thus challenge clinical implementation. This presentation presents a review of the clinically implemented ART in addition to in silico workflows that have been published on pelvic tumours.

Material and methods: Initial identification of papers was based on searches in PubMed. For each tumour site (prostate, gynaecological [gynae], bladder, ano-recatal), the identified papers were screened independently by two researches for selection of studies describing all protheses of an ART workflow: treatment monitoring and evaluation, decision and execution of adaptations. Both brachytherapy (BT) and external beam studies were eligible in the review.

Result: The review consisted of 43 clinical studies and 51 in silico studies. For prostate, 1219 patients were treated with online re-planning workflows, mainly to adapt prostate motion relative to bony anatomy. For gynae 1155 patients were treated with online BT re-planning while 25 ano-recatal patients were treated with offline re-planning, all to account for tumour regression detected by MRI/CT. For bladder and gynae, 161 and 64 patients respectively, were treated with library-based online plan selection to account for target volume and shape variations (Figure). In comparison to non-ART, sparing of rectum (prostate and bladder cancer), bladder (ano-recatal cancer) and bowel cavity (gynae and bladder cancer) was reported with ART.