OMICS Journal of Radiology

Hatami, OMICS J Radiol 2018, 7:4
DOI: 10.4172/2167-7964.1000e144

Editor's Note Open Access

Radiation Therapy

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Received date: August 27, 2018; **Accepted date:** September 22, 2018; **Published date:** September 30, 2018

Editor’s Note

What is radiation therapy?

Radiation therapy is a highly cost effective intervention that involves the use of controlled radiation for treating a wide range of cancers. High-energy radiation destroys cancer cells, by depositing energy, which damages the DNA of the cells and blocks their division and proliferation [1]. Curative radiotherapy is aimed at eliminating all cancer stem-cells from the primary tumour and the regional lymph nodes, while minimizing the damage to normal tissues. In the clinical setting, radiation therapy can be administered as the sole treatment. However, it can also be provided in combination with surgery, with it being given during (intra-operative), after (adjuvant), before (neoadjuvant) resection, or with systemic therapy. Sometimes radiation therapy can also be given for organ preservation (such as breast, larynx, urinary bladder, etc.) [2-4]. Furthermore, radiation therapy can provide relief from symptoms in locally advanced cancers or it can also be administered to eliminating pain (e.g. bone metastases) [5-7]. Nearly fifty percent of cancer patients undergo radiation therapy either for treatment or palliation [8].

Principles of radiation therapy

The basics of radiation therapy include a physics part and a radiation biology part. The radiation biology part involves the study of cell/organismal response to radiation. A key part of clinical radiation physics is the quantitation and documentation of the physical characteristics of the radioactive emissions, which entails detailed calibration studies. Radiation therapy was first used in January 1896, less than 3 months after the discovery of X-rays [8]. The first documented cure of a cancer (basal cell epithelioma) using radiation therapy was in 1899 [8]. During the 1920s and 1930s, studies revealed that single doses of radiation in large amounts have significant effects on tissue, which eventually lead to tissue damage after radiotherapy. Regaud and Coutard found that splitting large doses of radiation into smaller daily doses ("fractionating the treatment") significantly reduced the tissue toxicity while essentially producing the same tumor response [8]. The rationale for fractionated radiation therapy regimens is based on the four ‘R’s: repair, re-oxygenation, re-assortment, and repopulation [9], to which radio-sensitivity was added later [10]. One of the major limitations of early radiation therapy was the depth to which the radiation could penetrate without causing any damage to the skin. Early X-rays machines produced low-energy radiation in the range of 50 to 100 kV, which superficially deposit their energy, resulting in high skin doses. In the 1950s, the use of cobalt-60 units became very widespread. These machines could deposit maximum energy to up to 0.5 cm below the skin. However, at depths of 10 cm, most of the energy had been dissipated, making the treatment of deeper tumours an issue. The development of clinical linear accelerators in the 1960s, made it possible to deliver higher-voltage beams. Since, the sixties there has been an immense growth in the field some of the cutting-edge technologies in radio-oncology are advanced photon radiotherapy and particle therapy with protons or heavier ions. Nowadays, new technology can provide 3-dimensional images of tumours that accurately target the radiation beams to the tumor, thereby limiting the damage to adjacent organs [11].

Current limits of conformity

Cell survival after radiation therapy is modelled using an exponential function, which accounts for both- direct (α) and indirect (β), mechanisms of DNA damage. The α:β ratio is a read-out of the ability of the tissue(s) to repair the damage [12]. Radiation therapy in its current form is subject to certain limitations such as: (a) geographic misses caused by uncertain target identification, (b) geographic misses caused by movement of the tumor outside the treatment volume, and (c) changes in tumor volume during the course of treatment.

Challenges Associated with Radiation Treatment

A major challenge associated with optimization of radiation treatment is the presence of multiple conflicting objectives, such as: Covering the entire tumor volume, avoiding the dose hot spots in the target tumor, while sparing the surrounding organs and minimizing the complexity of treatment and delivery at the same time. Balancing these conflicting objectives poses a challenge while designing a new treatment plan.

The future of radiation therapy

The technology used in radiation therapy is improving by leaps and bounds. Recent advances have resulted in higher cure rates, shorter treatment durations, fewer side effects, and improved quality of life. Currently, real-time imaging that will enable compensation for involuntary movements on the patient’s part, such as breathing, is under development. Furthermore, certain clinical trials are investigating drugs that can sensitise cancer cells to radiation, making it easier to destroy them with radiation therapy. Simultaneously, protective drugs might help healthy cells recover from exposure to radiation. Personalized approaches to radiation therapy are also being explored.

Conclusion

Technological developments have revolutionised the clinical use of radiation therapy, but we the multifaceted nature of this discipline should not be forgotten [13]. Only by exploring all the aspects of radiation therapy such as: physics, chemistry, biology, medicine, and their interface will we manage to develop customized radiation therapy having better target delineation, dose escalation, dose fractionation, avoidance of normal tissue, and better prediction of the treatment response.

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