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Review

# Advances and future of Radiation Oncology

*Carlos A. Perez**, *Sasa Mutic*

*Department of Radiation Oncology, Mallinckrodt Institute of Radiology/Siteman Cancer Center, Washington University School of Medicine, 660 South Euclid Avenue, Campus Box 8224, Saint Louis, MO 63110 USA*

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ABSTRACT

*Aim:* Review of recent advances and vision for future developments in clinical practice of Radiation Oncology.
*Background:* There have been substantial research and technological developments in Radiation Oncology over the past 40 years.
*Materials and methods:* The relevant literature was reviewed and the authors offer their perspective on future opportunities for advancement in Radiation Oncology.
*Conclusions:* Significant innovative technological developments have been introduced in the practice of Radiation Oncology, with more precise target delineation and tracking and three dimensional treatment planning, optimal delivery of radiation therapy to the target and lower doses to surrounding Organs at Risk. This dose optimization and adaptive therapy have enhanced the role of Radiation Therapy to more effectively treat patients with cancer. Further creativity and refinements will continue to advance the field into new applications of ionizing radiations in cancer therapy.



## 1. Introduction

Radiation Oncology is one of the pillars of multidisciplinary care of the patient with cancer. In the past 50 years, and especially the last 20, Radiation Oncology has experienced dramatic technological innovations (Fig. 1), leading to image-based complex three-dimensional treatment planning and delivery of radiation therapy, using 3D-Conformal or Intensity Modulated Radiation therapy (IMRT), with increased precision in dose delivered to the target volume(s), while sparing adjacent normal structures (Organs at Risk, OAR).[1] The dose-rate effect of external beam radiation therapy with conventional linear accelerators is governed by the overall beam-on-time. With the advent of flattening-filter-free accelerators and hypofractionation (high dose per fraction) radiation therapy schemas, biological effects of external beam dose rate will need further investigation.[2]

## 2. Treatment planning and dosimetry

Requirements on dose conformality, smaller PTV margins and the sharp peripheral dose gradient of these techniques require a more stringent Quality Assurance Program. Widespread use of electronic clinical and dosimetry records and informatics methodology will add reliability to the data acquired. Exponential growth of medical imaging modalities (CT, MRI, US), including image fusion have enhanced our ability to diagnose cancer at earlier stages and to more accurately stage the tumor. The improvement in staging accuracy has enabled us to better tailor therapy based on the characteristics and

* *Corresponding author at*: 1415 South Fairway Avenue, Springfield, MO 65804, USA. Tel.: +1 314 910 7095.
E-mail address: cperez@radonc.wustl.edu (C.A. Perez).
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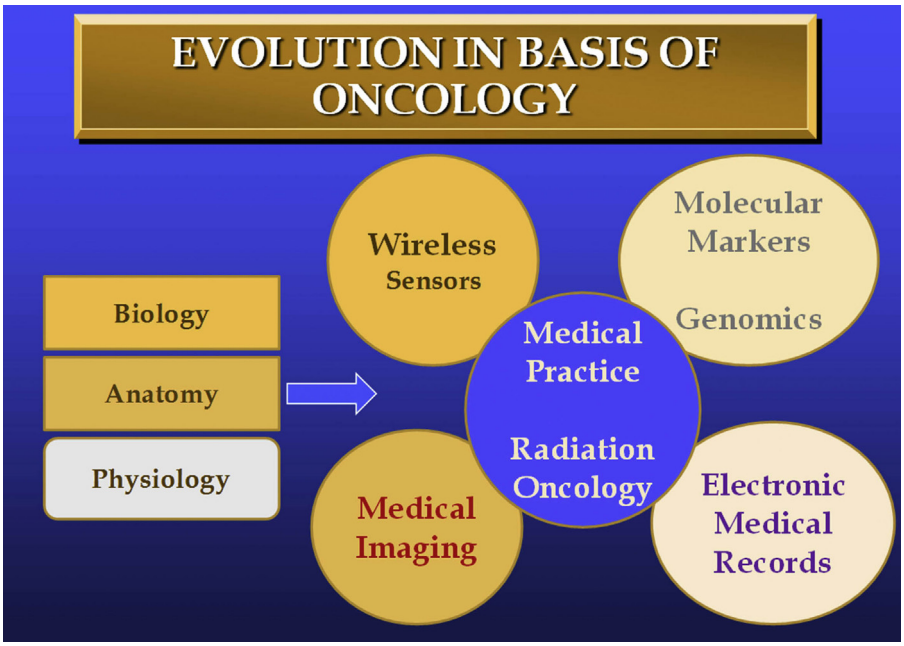


**Fig. 1 – Evolution in basis of Radiation Oncology.**

the extent of the individual patient's tumor. In the past 10 years there has been an increasing use of functional PET imaging (18F-FDG or other specific radiotracers for hypoxia, cellular proliferation, angiogenesis, etc.) or magnetic resonance spectrometry, with better delineation of target volumes, particularly clinical target volumes.[3]

## 3. In-Room imaging

In-Room on-line imaging devices, including Cone-Beam CT (CBCT), commercially available have facilitated the implementation of Image-Guided Radiation Therapy (IGRT). Implanted target tracking devices enhance our ability to more accurately localize the target for treatment. 4D CT scanning with faster scanners and treatment planning has facilitated correction of target motion in the lung and upper abdomen, including Active Breathing Control Techniques. As a corollary, stereotactic hypofractionated techniques have been introduced in the treatment of brain, lung, and tumors in other anatomical sites.

While the CBCT and these other technologies have come a long way, we are still unable to image and quantify the true extent of soft tissue tumors on daily basis and during the radiation delivery. This undoubtedly remains one of the last frontiers in Radiation Oncology and the recent technological developments and research indicate that we will have these capabilities in the upcoming years. Internal implantable electromagnetic or transmission dosimeters may eventually facilitate the verification of actual radiation dose administered to the target and OAR.

As to the future, we envision an active role of Radiation Therapy in combination with cytotoxic or biological agents. While the effect on the tumor may be enhanced, so will be the sequelae in OAR. This will require more rigorous treatment planning and Quality Assurance, to diminish toxicity and unintended radiation effects.

## 4. Molecular biology and genomics

The application of genetic profiling and DNA mapping, already used by Medical Oncologists to select patients that will respond to a specific antitumor agent or to protect normal tissues may eventually be introduced in the practice of Radiation Oncology.[4] A Holy Grail of research in Radiation Oncology is the identification of specific genes or molecular markers to both to predict response of tumors or normal tissues to a prescribed dose of irradiation.

For the past 50 years in some tumors combinations of cytotoxic agents and radiation therapy have improved outcomes in many patients. In the future combining genetically engineered biological agents or molecular compounds may enhance the effects of radiation therapy on some cancers.

Regardless of the radiation modality we must strive to optimize dosimetric precision, in radiation treatment planning, delivery and verification. One of the key elements in delivery of radiation therapy that is still to be attained is accurate assessment of the true dose, $D_A$, delivered to the patient. Despite all of the advances in treatment planning, imaging, and delivery, the true impact of dynamic nature of cancer patients (inter and intra fraction motion and patient changes) remains unknown for the majority of radiation therapy patients.[5] The existing and upcoming developments including: fast image acquisitions for daily treatments as well as during the actual radiation delivery, auto contouring and deformable contour propagation, and fast dose calculations will enable much better quantification of the $D_A$. The knowledge of $D_A$ will enable further optimization of tradeoffs between doses delivered to tumor volumes and those delivered to Organs at Risk. A better