

## Image-Guided Radiotherapy-On Center Stage

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Each year ushers in new and innovative radiotherapy technologies for the treatment of cancer, to the wonderment of patients and their radiation oncologists alike. In 2004, one million Americans with cancer were treated by radiotherapy-88 percent of whom received external beam radiation treatments from a linear accelerator [1]. In the current spotlight of the Journal of Radiology are radiation linear accelerators that integrate image-guidance into their delivery system, elevating confidence in delivered radiation dose to cancer targets.

Linear accelerator-based radiotherapy, an actor on the therapeutic anticancer stage for the past 50 years, acts indiscriminately of cancer cell types and cell surface markers. Both cancer and normal cells sustain potentially lethal DNA damage, with normal cells often repairing radiation-induced damage quickly after exposure [2]. Today, local control of cancer may happen through use of radiation treatment portals depositing radiation dose that use narrow margins around a cancer target. This is done all in an effort to spare healthy normal tissues from intolerant radiation dose. To provide tight radiation dose margins requires high mechanical accuracy of linear accelerators and even better accuracy in patient positioning. There is an unmet need for radiotherapy technology that assists in accurate patient positioning prior to radiation delivery. Up-to-now, this need has been met by image-guided radiotherapy.

With new celebrity-like buzz surrounding emerging novel radiotherapy platforms, radiation oncologists and medical physicists must screen each radiotherapy platform's overall technologic portfolio. Critical to a platform's performance is its linear accelerator treatment isocenter. The treatment isocenter is the ideal isocenter point about which all linear accelerator motions occur. Also, the treatment isocenter references all images used in image-guided radiotherapy. Perhaps most compelling, it is the position that informs algorithms calculating radiation dose prescription and resultant radiation dosimetry. While the treatment isocenter is optimal, in actual radiation delivery, a radiation isocenter serves as the focal point for linear accelerator movements. Rather than being a point in space like the treatment isocenter, the radiation isocenter is thought of as a small sphere in space. The radiation isocenter deviates, on a small scale in all directions, from the treatment isocenter based on positional uncertainties of the mechanical gantry, collimator, and couch rotation [3]. The coincidence of the treatment isocenter and radiation isocenter in clinical practice is limited ideally to  $\pm$  one millimeter for stereotactic radiosurgery and  $\pm$  two millimeters for intensity modulated radiation therapy [3]. Novel radiotherapy platforms delivering conventional or ablative ( $>7$  Gy per fraction) radiation by integrated robotics and fine-tuned microleaf collimators must be held to even greater accuracy in radiation isocenter alignment. Imagine image-guided radiotherapy platforms that allow for intrafraction and interfraction compensation for cancer target movement as a consequence of physiologic change in organ size, shape, and motions due to respiration, heartbeat, swallowing, and differential rectal and bladder fillings.

Image-guided radiotherapy provides a means to align precisely the radiation isocenter to patient cancer targets. Current image-guided radiotherapy technology allows sophisticated computer software to merge multimodality images through image registration and fusion as a way to guide linear accelerator hardware for treatment

(e.g., 2- $^{18}$ F]fluoro-2-deoxy-D-glucose positron emission tomography superimposed upon computed tomography radiation planning [4]). But, technical limitations of image slice thickness (the axial extent of the patient over which the slice is averaged) and image index (the separation between slice centers along the direction of couch motion) complicate further refinement. Cancer target motion management is an active area of research. Future study may be directed at feature-based recognition (e.g., an added stereotactic localizer around the patient) or region-based recognition (i.e., image intensity, texture, gradient detection) of cancer targets by integrated on-board imagers that navigate linear accelerator motion on-the-fly during radiation delivery.

Pioneering radiotherapy technologies exist. It is tempting to speculate that either agile non-coplanar multileaf radiotherapy or non-coplanar dynamic wave arc radiotherapy, guided by integrated on-board imagers, are in the radiation oncologist's future. The cautious implementation of such technologies, vetted in their performance by clinical trials, will translate into healthier cancer patient survival.

### References

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