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● *Editorial*

CLINICAL ASPECTS OF IMRT—PART III

At the present time, the clinical implementation of intensity-modulated radiation therapy (IMRT) is in its infancy. The early IMRT delivery concept was pioneered by Dr. Takahashi and colleagues from Japan about 35 years ago,[1] who planned and delivered dynamic treatments using the first multileaf collimation (MLC) system. However, the MLC system was managed using a mechanical control system to shape the beam to the target as the machine rotated around the patient. In the later part of 1970s, the use of computers to control the beam delivery system was reported;[2] however, at that time, the maturity of computer and linear accelerator technology was not at the level of sophistication feasible for clinical implementation of IMRT. In late 1980s, Brahme and colleagues suggested a new generation of radiotherapy equipment.[3] Their suggestions were fundamentally different from conventional radiotherapy, with the use of nonuniform intensity fields to achieve an improved dose distribution. This task requires a higher level of sophistication from computers to generate optimized nonuniform intensity fields based on inverse planning algorithm. At the same time, the accelerator technology was at a stage where the beams were shaped with a computer-controlled multileaf collimation system. Today, it is feasible to implement IMRT with appropriate computer software and hardware to generate optimized dose distributions based on nonuniform intensity fields deliverable through a computer-controlled beam delivery system. Recent publications on technology trends reported that 10% of radiation oncology sites were able to perform IMRT as of the year 2000;[4] representing an increase from 4% in the year 1998. It is anticipated that at least 35% of the sites are planning to acquire IMRT by the year 2002.

A review of the literature indicates that a variety of IMRT techniques and equipment have been proposed. Scanned photon beams and electron beams available on the Scanditronix Racetrack Microtron System were proposed for IMRT;[3] however, because this equipment is only available at a few institutions, the accessibility of this technology is limited. Tomotherapy referring to the delivery of narrow arc beams of intensity-modulated radiation is more accessible and is the first IMRT equipment to be commercially available for clinical use.[5] This tomotherapy is identified as sequential tomotherapy, whereby the treatment couch is stationary during beam delivery. On the other hand, during helical tomotherapy, both the gantry and treatment couch move continuously as the beam is left on.[6] A conventional MLC system that is part of a linear accelerator has also been used to modulate radiation beams for IMRT. The delivery process in which the MLC leaves sweep across the target while the beam is on is called the “sliding window technique” or dynamic MLC (DMLC). Another delivery technique called the “step-and-shoot” or static MLC (SMLC) delivers a series of MLC-shaped fields (segments or subfields) at a stationary (fixed) gantry angle to generate an intensity-modulated profile. The third delivery technique using conventional MLC is the intensity-modulated arc therapy.[7] In this delivery technique, the MLC changes its shape continuously during gantry rotation while the beam is on. The use of a physical modulator is the simplest form of IMRT delivery technique;[8] it requires the placement of a physical filter across the radiation beam at a particular gantry angle. However, the fabrication of the physical modulator is time consuming and the implementation process is considered cumbersome because it requires the therapist to enter the treatment room and to manually insert the modulator into the tray mount. As assessed, the most likely emergence of IMRT would be through the use of tomotherapy and/or MLC-based IMRT.

The Peacock system is the first commercially available system to perform IMRT. This system developed by NOMOS received Federal Food and Drug Administration (FDA) clearance for its hardware in 1995 and its totally integrated system in 1996. This IMRT delivery technique uses the binary multileaf intensity-modulating collimator (MIMiC) to modulate the beam intensity to generate the nonuniform fields and hence is referred as MIMiC-based IMRT. The MIMiC must be properly attached to the linear accelerator and aligned to the beam axis. It has basically its own operating system and is independent of the linear accelerator. The beam modulation instructions are created using the CORVUS treatment planning system. The CORVUS system uses an

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inverse planning algorithm to seek optimized objective functions based on simulated annealing techniques. Because the Peacock system consists of new hardware and software separated from a typical linear accelerator and a conventional treatment planning system, familiarization with this new equipment is therefore critical. *Medical Dosimetry* (Volume 26, No. 1, 2001) devoted the first special IMRT issue on MIMiC-based IMRT.

The second special IMRT issue (*Medical Dosimetry*, Volume 26, No. 2, 2001) was devoted to MLC-based IMRT. The delivery techniques of MLC-based IMRT are very dependent on the design of the MLC. Because different vendors have different MLC designs, the philosophy of the MLC-based IMRT is therefore much more complex. The physical characteristics of the MLC have to be evaluated for IMRT during commissioning. This evaluation is important to account for the radiation leakage and also the logistics necessary to create deliverable radiation fields. These unique features, such as single- or double-focused MLC, tongue-and-groove effect, or leaf motion restrictions have to be taken into account in the inverse-planning algorithm. After the nonuniform fields are determined from the algorithm for a particular field, a leaf-sequencing algorithm is needed to create deliverable segmentations that are efficient in reducing the overhead time. It is now possible to deliver IMRT within a reasonable time, around 20 minutes for about 120 segments in the static MLC technique. Like MIMiC-based IMRT, MLC-based IMRT is also new; hence, dose validation is an important component in commissioning and quality assurance. In general, absolute dose measurement is made using ion chamber and relative dose distribution using film dosimetry. There is also tendency to have an independent dose calculation check as a means of dose validation. However, it does not represent an actual measurement of dose delivered. Because the conventional MLC system is often part of a linear accelerator, there is a tendency to implement IMRT with the purchase of a new linear accelerator. Whether or not it is possible to implement IMRT in a community hospital should be evaluated in a careful manner, addressing the issues of expertise and manpower. Many of these issues were addressed in the second special IMRT issue of *Medical Dosimetry*.

Advances in radiation therapy have been toward the use of imaging technology to better delineate target in 3 dimensions. In addition, the treatment planning and beam delivery techniques have been developed for 3D conformal radiation therapy (3D-CRT). These techniques have made it possible to deliver high radiation dose clouds to conform to the tumor volume.[9] Still, there are situations where 3D-CRT is not adequate, especially for concave-shaped targets or targets in close proximity to sensitive normal structures. IMRT was introduced to overcome these limitations. However, while this advance may solve many obstacles, it also introduces new ones. The major change to IMRT requires familiarization with dose prescription. Now the dose prescription requires specification of desired dose outcomes and acceptable limits such as the allowable volume below the prescribed dose, the maximum dose, and minimum dose allowed. Likewise, these desired goals have to be specified for sensitive structures as well. After the treatment plan has been generated, it is imperative that the dose distribution be evaluated slice-by-slice through the treatment field. In addition, unforeseen symptoms of skin redness or ulceration in unusual regions of the patient may be anticipated based on the review of the dosimetry. Even with this careful approach, IMRT has already demonstrated promising results in the treatment of the head-and-neck region and prostate malignancies.[10,11] The dosimetric advantages are the dose sparing of the parotid glands and the delivery of different dose levels to separate target volumes. This third and last special IMRT issue of *Medical Dosimetry* is dedicated to the clinical aspects of IMRT. While our radiation oncology community embraces IMRT with optimism, it cannot do the impossible. The entry of desired dose goals and beam parameters must be realistic not to violate the law of physics; for example, it is not possible to have a simultaneous high dose to the target and zero doses to sensitive structures surrounding it. Because IMRT is new, its full potential has yet to be realized. It is anticipated that when IMRT is fully developed, it will significantly alter the way we practice radiotherapy.

The compilation of articles for these three special IMRT issues in *Medical Dosimetry* is only possible with the support of the experts in IMRT. Their willingness to share their experiences signifies their strong interest in supporting our radiation oncology community so that IMRT can be implemented clinically in a safe and efficient manner. The significant amount of time and effort invested in writing these articles and the authors' willingness to undergo review are sincerely appreciated by the guest editors. It is the hope of the guest editors that these IMRT special issues would allow familiarization and conceptual understanding of IMRT for the medical physicists, medical dosimetrist, radiation oncologists, and radiation therapists. In addition, the material presented would be contributory to those interested in the clinical implementation of IMRT program at their institutions. The guest editors take this opportunity to thank all authors for their contributions.

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