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Intensity-Modulated Radiation Therapy in the Management of Head and Neck Cancer

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1. INTRODUCTION

Head and neck cancer represents a complex collection of tumors involving mucosal surfaces of the upper aerodigestive tract. Approximately 43,000 cases are diagnosed each year in the United States, representing 3 to 4% of all cancers (1). Worldwide, head and neck cancer represents a much broader oncology problem (~500,000 annual cases), with tumor development strongly associated with chronic tobacco and alcohol use.

Radiation plays a central role in the treatment of head and neck cancer. New radiation delivery techniques offer a powerful potential to diminish the spectrum and severity of radiation toxicities for head and neck cancer patients. For many decades, conventional head and neck radiation techniques have involved treatment with generous opposed lateral beams to encompass the known primary tumor and upper cervical lymphatics. This classical technique produces a relatively homogeneous dose distribution that allows excellent target dosing while minimizing hot and cold spots. However, owing to the tight proximity of tumor targets and normal tissue in the head and neck region, many uninvolved structures including salivary glands, spinal cord, auditory apparatus, optic apparatus, mandible, and vocal cords can unnecessarily receive high doses of radiation.

Intensity-modulated radiation therapy (IMRT) represents an advance in technology that allows the radiation oncologist to “shape” radiation dose profiles around normal structures while fully dosing the tumor and at-risk nodal regions. This capacity for improved dose distribution affords considerable opportunity to reduce the overall toxicity profile associated with head and neck radiation. However, despite high promise, IMRT use remains in its early stages, and must be delivered with strict attention to quality assurance, as relatively few long-term clinical data exist. Furthermore, IMRT is quite labor intensive for the practitioner, with a strong dependence on physics and quality assurance support, thus leaving open the possibility for significant heterogeneity across practitioners and institutions.

1.2. What is Intensity-Modulated Radiation Therapy?

IMRT refers to a specific technique of linear accelerator-based radiation therapy whereby radiation beams are modulated in such a manner as to produce highly conformal dose distri-
A primary objective of IMRT is to reduce dose to selected normal tissue structures in an effort to preserve function, while maintaining full dose delivery to tumor targets. In conventional head and neck radiotherapy, the fields are shaped by blocks and potentially modulated by wedges or custom tissues compensators \(^{(2)}\). In contrast, IMRT is delivered by either multiple modulated static fields (step and shoot) or by a continuously rotating gantry (serial tomotherapy). As the radiation is delivered, specific subsections of each field, known as beamlets, are delivered at different intensities to produce highly conformal dose distribution around irregular shapes (Fig. 1).

**IMRT planning is conceptually distinct from conventional radiotherapy planning.** With conventional head and neck planning, the radiation oncologist will shape beams by viewing anteroposterior (AP) and lateral radiographs of the head and neck. A generous field margin is used to account for setup variation and physical characteristics of the beam itself. The radiation dose and profile are then calculated using broad and simple beams in a process known as *forward planning*. In contrast, IMRT planning requires the up-front designation of specific targets (gross tumor, elective nodal regions) and avoidance structures (spinal cord, salivary glands, optic apparatus, and so on). Dose specifications are then defined for each of the targets and avoidance structures. The computer planning software then creates a series of beam angles with modulation patterns that strive to achieve the physician’s dose prescription goals. This process is known as *inverse planning*.

**1.3. History**

IMRT was first conceptualized in the 1960s. However, it was not until the 1980s and 1990s that the computing capability needed for the complex inverse planning algorithms became commercially available \(^{(3)}\). In 1994, the NOMOS Peacock system was introduced as the first commercial IMRT delivery unit. The Peacock system required that an existing linac be retrofitted with a beam modulation device known as a dynamic multivane intensity-modulating collimator (MIMiC). The MIMiC allowed a radiation beam to be continuously modulated as the gantry rotated. This particular form of IMRT is called serial tomotherapy, as “slices” could be treated by a continually rotating gantry. More recently, other forms of IMRT have come into common use. Step and shoot IMRT represents another commonly used technique whereby multiple static beams are subdivided into “beamlets.” Each individual beamlet is then modulated. Helical tomotherapy is similar to the Peacock system but has the added features of a

**Fig. 1.** Transverse, sagittal, and coronal images of head and neck IMRT plan for a patient with squamous cell carcinoma of the right tonsil. The left parotid gland (arrow) is specifically spared from high-dose radiation (mean dose of approx 22 Gy for left parotid).