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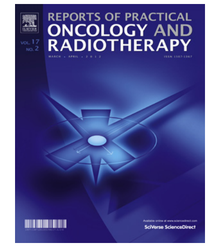

Review

Current status of IMRT in head and neck cancer

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ABSTRACT

Background: IMRT provides highly conformal dose distributions creating non uniform spatial intensity using different segments in the beam.

Material & Methods and Results: Different retrospective studies have shown a high capability of IMRT to treat tumours close to the base of skull. Prospective studies have shown a decrease in xerostomia compared with conventional 3D conformal treatment (3DCRT). Modulation of intensity is performed by the movement of the multileaf collimator (MLC) that can deliver the radiation in different ways, such as static field segments, dynamic field segments and rotational delivery (arc therapy and tomotherapy). There are slight differences among the different techniques in terms of homogeneity, dose conformity and treatment delivery time.

Conclusions: The best method to deliver IMRT will depend on multiple factors such as deliverability, practicality, user training and plan quality.

1. Background

Radiotherapy (RT) is the cornerstone of treatment for locally advanced head and neck cancer (LAHNC). The main goal of radiotherapy is to provide the maximum loco-regional control with the minimum toxicity. However, the complex relationship between tumours and critical structures, with concave shapes and very close interrelation, limits the ability of conventional radiotherapy to shape the doses to the target volumes and to spare the organs at risk (OAR). In intensity modulated radiation therapy (IMRT), modulation of the beam fluence permits to deliver a non-uniform intensity to the target,[1] increasing the conformation of the high dose to the tumour. The aim of this revision is to review the basis of IMRT and different methods to deliver this technology.

2. Concept of IMRT and differences with 3DCRT

The transition from conventional 2D treatment planning to 3D conformal treatment (3DCRT) has been an important advance in radiation technology. In 3DCRT, simulation and planning are performed based on computed tomography images, achieving a precise tumour definition and a more accurate dose

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calculation by accounting for axial anatomy and complex tissue contours. Moreover, it permits to use multiple fields, including oblique and non-coplanar, which together with variations in weight, wedges and shaped blocks or multileaf collimators (MLC) permits to achieve adequate tumour coverage and normal tissue sparing.

One of the main differences between IMRT and 3DCRT is the ability to conform the dose distribution to the target. In most of the techniques to deliver IMRT, MLC divides beam fields in different segments, or creates "segments" moving across the field, getting a different fluence in each beam. Modulation of the fluence creates non-uniform spatial intensity distributions that produce highly conformal dose distributions.

3. Steps involved in IMRT

Three of the most crucial parts of IMRT are target delineation, treatment planning and quality assurance. Because of the resulting steeper absorbed-dose gradients, optimal IMRT requires more accurate delineation of both tumour and normal tissue than does conventional radiotherapy. However, there is a substantial heterogeneity in target definition and prescription among radiation oncologists with IMRT expertise that will make it difficult to assess the success of the treatment. Efforts to standardize and simplify the IMRT process have been suggested for Head and Neck IMRT practice.[2] Moreover, additional normal tissue often has to be delineated because structures that are not specified are not considered in the planning process, and may receive a significant high absorbed dose. Optimization is a key point in radiotherapy planning. Using MLC, it is possible to create a wide range of beam intensities employing different segments. Optimization explores these possibilities to find the optimum intensity pattern for the desired outcome, that is specified with dose and volume constraints. The planning process can be summarized in three points: first, the desired outcome is specified in terms of dose and volume constraints and objectives for OAR and PTV using a system of priorities. Second, an objective function will be constructed to specify the goodness of the plan. During the optimization process, a candidate fluence distribution map with a cost function as close as possible to the objective function is searched. Finally, once the optimal fluence map is found, it must be converted into deliverable field segments according to the specified method of delivery, considering the limitations of the treatment unit due to physical and mechanical characteristics of the MLC. Dose calculation algorithms based in beamlet optimization, such as convolution/superposition (each field is discretized into a grid of beamlets with distinct intensity), or aperture-based optimization (the best set of aperture shapes is found to deliver the intensity pattern without discretization of the field in beamlets), will provide accurate absorbed-dose calculations.[3]

4. Image-guided radiotherapy (IGRT)

Delivery of a high radiation dose to the clinical target volume avoiding critical structures increases the complexity of treatment planning and delivery and also the precision required for localization and for securing geometrical precision. IMRT has an excellent capability to put the dose where it is needed on a screen. However, it is necessary to have in mind that planning CT is a snap shot and may not represent the every day location. The advent of on board cone beam computed tomography (CBT) and in room CT with high soft tissue contrast has opened new opportunities for higher accuracy in radiotherapy.[4] Other image-guidance capable systems that have an important role in IGRT are ultrasonography, MRI, and optical imaging techniques.[5] Cone beam may be performed before every fraction and corrections are made on line after aligning with the planning CT, reducing both the systematic and random position.[6] Thus, the information derived could be used to evaluate more accurately the PTV margin required for IMRT. Validated protocols of systematic error correction can minimize the IGRT workload.[7]

Although supplementary imaging involved in IGRT exposes the patient to more radiation, with an extra dose of 0.1–3% of the treatment total dose, this technique guarantees a precise administration of radiation at the right place. Moreover, a reduction in the PTV margin will decrease the dose to critical structures.[8]

Patients with head and neck cancer may experience significant changes in the tumour volume and anatomical structures during the radiotherapy course. This issue has a special significance considering that IMRT achieves highly conformal dose distributions. It has been shown that the tumour volume can dramatically decrease during a treatment course, and that re-planning considering this volume change would translate into a substantial sparing of the surrounding critical structures.[9] Moreover, patients treated also with chemotherapy may loose considerable weight during their full radiation treatment, and dose in critical structures may change as a result of this weight loss.[10] Image guidance can allow to visualize the anatomical changes during the treatment, and if dose distribution at some point reveals that there are low dose regions or a higher dose region in a critical structure, subsequent fractions could be re-planned.

5. IMRT: clinical or dosimetric benefit?

Different retrospective studies have shown the increased therapeutic ratio achievable with IMRT in tumours close to the base of the skull, such as paranasal sinus cancer.[11] One of the most frequent chronic and invalidating side effects in LAHNC is xerostomia, with a well documented association with mean doses to the parotid gland of more than 26 Gy.[12] Moreover, it has been recently shown that with parotid doses lower than 25–30 Gy function recovery is substantial and a return to pre-treatment levels may be achieved in 2 years after RT.[13] A recent randomized study with 94 patients with locally advanced pharynx cancer has shown that IMRT resulted in a decrease of xerostomia (Grade $\geq$ 2) at 12 and 24 months compared with 3DCRT, with an absolute benefit of 54% at 24 months.[14] IMRT allows to achieve heterogeneous dose distributions and can be exploited to treat simultaneously elective and primary volumes decreasing the overall time of the treatment, with a potential