Progress in radiotherapy technology for non-radiation oncologists

Vincent Gregoire

Radiation Oncology Department and Centre for Molecular Imaging and Experimental Radiotherapy, Université Catholique de Louvain, St-Luc University Hospital, Brussels, Belgium

During the second half of the last century, key technological innovations have tremendously modified the daily practice of radiotherapy, leading to substantial improvements in treatment delivery and outcome [1]. The introduction of linear accelerators (linacs) in the early 1950s, the increasing use of computed tomography (CT) and magnetic resonance imaging (MRI) for target volume delineation from the 1980s on, and more recently in the late 1990s the availability of advanced treatment planning systems together with multi-leaf collimators have progressively contributed to a more targeted and conformal dose delivery, i.e. a better dose distribution within the target volumes while sparing surrounding normal tissues. In addition, many linacs are currently equipped with electronic imaging systems for verification of patient positioning, thus enabling better conformity between the planned dose and the dose that is actually delivered. All these technical innovations have led to the ability to deliver a much higher dose to target volumes, thus possibly increasing local tumour control, while minimising the dose delivered to the surrounding normal tissues, thus possibly decreasing treatment morbidity.

In intensity modulated radiation therapy (IMRT), the dose delivered from each beam direction is non-uniform but the collective set of beams can produce dose homogeneity in a target volume which is comparable to conventional radiotherapy and may result in superior conformality, especially for concave shaped target volumes. For example, concave dose distributions are required for tumours surrounding the spine and for treatment of prostate cancer with seminal vesicle involvement. Examples of multiple organs at risk are common in head and neck cancer where the parotids, eyes, brainstem, auditory apparatus, thyroid, spinal cord may all be organs at risk. IMRT requires a new approach to the whole treatment procedure from patient immobilisation prior to imaging through to beam delivery. Implementation of IMRT requires knowledge of setup uncertainties with or without daily setup verification, adequate selection and delineation of target volumes based on optimal imaging modalities, dose optimisation based on dose-volume constraints, appropriate dose prescription and specification, and quality control of both the clinical and physical aspects of the entire procedure.

The use of IMRT is growing rapidly, especially in the USA and in the Western world. In a survey performed in 2003 in the USA, among 168 respondents randomly selected, one third were using IMRT [2]. By 2006, the figures may have doubled. Among the sites treated by IMRT, head and neck malignancies and prostate cancers are by far the most common, followed by central nervous system, lung, breast and gastrointestinal tumours.

However, very few prospective randomised trials that demonstrate any superiority of IMRT over conventional treatments both in term of efficacy and morbidity have been reported. For head and neck and prostate cancer, no randomised study has been reported, although such a study is being conducted in England and should soon be reported. For prostate cancer, it is likely that such comparison will never take place. For breast, a randomised study was performed comparing IMRT with standard tangential wedged fields. Donovan and colleagues reported that a better dose distribution was achieved with IMRT [3], but no data on clinical outcome have been reported yet. Only retrospective studies are available to demonstrate the potential benefit and possible drawbacks of IMRT over conventional radiotherapy. These data have been mainly accumulated for head and neck and prostate tumours. For head and neck, the most convincing data on the increased therapeutic gain achievable with IMRT are from tumours close to the base of the skull such as nasopharyngeal and sino-nasal cancers, for which a higher rate of local control and a lower incidence of complications have been reported in comparison with conventional techniques [4,5]. A substantial reduction in late radiation-induced toxicity such as xerostomia has also been extensively documented following the use of IMRT for pharyngo-

laryngeal squamous cell carcinomas (SCC) [6–8]. A few retrospective studies have also reported that, despite the high conformality in dose distribution, geographical miss was rather uncommon in IMRT for pharyngo-laryngeal [9–12]. For prostate cancer, the largest series comes from the Memorial Sloan Kettering Cancer Centre, which has reported over 772 patients treated with IMRT with doses in excess of 81 Gy (roughly 20% higher than the dose used in conventional treatment). In the study only 4.5% of patients developed a grade 2 rectal toxicity (moderate diarrhea, excessive rectal mucus or intermittent bleeding) and none experienced a grade 3 or greater toxicity [13].

Because of the high degree of conformality achieved with IMRT the optimal process for choosing target volumes, dose levels and evaluation metrics is under development. A consensus regarding the selection and delineation of adequate target volume in several treatment sites is important for making further progress. In this framework, it is likely that IMRT will benefit from the recent developments in molecular imaging that have created opportunities to reveal the complexity of tumour biology, and thus of target volumes [14]. Secondly, IMRT through its conformality and its consequent sparing of normal tissues challenges the 'dogma' of the 2 Gy per fraction. Clinical protocols using higher dose per fraction or different dose per fraction in various parts of the target volumes have been elaborated but are still under evaluation. Last but not least, radiation oncologists have recognised the necessity to incorporate a changing patient representation in time. Incorporating 'adaptive treatment' into the planning and delivery processes helps to ensure that patients are adequately positioned on a daily basis, and also helps to track the modifications in shape and/or nature of the target volumes. Bentzen recently proposed the term 'theragnostic' to describe the use of molecular imaging as a basis to adapt the dose prescription as a function of time [15].

Conflict of interest statement

None declared.

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