ABSTRACT

Ionizing radiation like X-rays and Gamma rays are invariably used for cancer treatment almost immediately after their advent in the later part of the nineteenth century. From then, till recently, 2D traditional radiation techniques were invariably employed for cancer treatment. Such techniques were usually guided by planners experience and the radiation parameters are then adjusted using a method known as forward planning, until a satisfactory dose distribution is achieved. This technique is usually characterized by larger field shapes and uniform fluence beams to take care of the possible involvement of disease in and around the tumor. In other words, larger normal tissue was irradiated from prophylactic perspective. Higher tumorocidal doses were thus impractical because of possible normal tissue complications. For instance, in case of cervical, prostate and head-and-neck tumors, target volumes are either irregular or concave in shape in close proximity to critical organs like the bladder, rectum, spinal cord, parotid glands etc. Delivery of high tumorocidal doses were not possible with conventional techniques. In non-small cell lung cancer, a usually employed tumorocidal dose of around 60 Gy with conventional technique is not good enough and hampers the tumor control in >80% of the patients. But, a good correlation exists between tumor dose and tumor control. Thus, increase in tumor dose using recent techniques like intensity-modulation could improve local control. Thus, for many treatment sites, in spite of higher dose requirements, tumor doses were restricted to the limit tolerated by near critical organs and normal tissues. Hence the greatest challenge for radiation therapy or any cancer therapy is to attain the highest probability of cure with the least morbidity. This could be realistic if radiation is delivered such that the tumor receives sufficient doses while simultaneously sparing surrounding critical organs and normal tissues.

The advent of intensity modulation of X-rays and Gamma rays opened up huge scopes for delivering required tumorocidal doses without exceeding normal tissue tolerance doses.

Thus, the objective of this work is to assess the efficacy of the recent treatment technique, namely intensity modulated radiation therapy (IMRT) plans for different treatment sites like prostate, cervix, oropharynx and lung. For each treatment site, IMRT plans were compared with many other possible planning techniques like conventional, 3DCRT, Field-in-Field (FIF), volumetric modulated arc therapy (VMAT) as applicable to that site. To facilitate comparison, many physical and biological indices were evaluated. The physical indices include: different homogeneity indices, conformity index, dose-volume parameters (D_x and V_x), mean dose, maximum dose etc. The biological indices include: tumor control probability (TCP), normal tissue complication probability (NTCP) and uncomplicated tumor control probability (UCP). BIOPLAN software was used for evaluating biological indices and to study interrelationships between them. External beam plans (conventional, 3DCRT, FIF, IMRT and VMAT) were created using either Preciseplan or Eclipse planning system commissioned for Precise digital and Trilogy Silhouette accelerator respectively. Brachytherapy plans were created using Oncentra planning system. All the plans were created and normalized such that, similar dose distributions result for planning target volumes. For this fixed dose distribution of tumor, critical organ doses were evaluated and analyzed.

In the first study, the influence of photon energy on IMRT plans was analyzed for prostate tumors. Eight patients with localized prostate cancer were studied and relative efficacy of 6 MV IMRT plans to 15 MV IMRT plans were tabulated based on different physical and biological indices. In general, dosimetric comparison of all above parameters showed that there was little difference between 6 MV and 15 MV groups. Hence the study recommends using low energy for IMRT as high energy is well-known to produce neutron contamination.

In the second study, nine patients with cervical cancer were studied. The emphasis was on doses to bone marrow (BM) as only limited literature references were available on this subject. Reduction of doses to bone marrow could reduce hematologic toxicity (HT) and benefit the patients. Low and high energy IMRT plans were compared with conventional two field (2F) and four field box (4FB) techniques. Analysis of various physical parameters revealed that, IMRT plans can significantly reduce the bone marrow doses and are expected to reduce the hematologic toxicity.

The third and fourth studies discuss oropharynx and lung tumors respectively. Both studies compared 6 MV and 15 MV IMRT plans with 3DCRT and FIF 3DCRT techniques using many physical and biological indices. Their general conclusion is that IMRT could be a viable solution to these treatment sites. Improved therapeutic index was observed in IMRT plans that could be achieved with dose escalation to tumors. Further, results showed that parotid gland and spinal cord doses are less in 6 MV IMRT when compared to FIF 3DCRT.

Similarly, in the last study, based on the analysis of physical indices, IMRT was found to be a potential alternative to high dose rate brachytherapy in certain situations.

From the above studies, it is quite clearly evident that IMRT could be a viable solution for prostate, cervix (initial and boost treatments), oropharynx and lung cancers. All these studies are retrospective and dosimetric in nature and hence suffer from inherent limitations in that approach. All radiobiological predictions are based on existing knowledge on radiobiological parameters which are approximate representations of the whole population and they seem to have wide variations from individual to individual. The technology is not refined enough for estimating patient-specific radiobiological parameters. Till now, physical dose distributions and associated indices were extensively used to access biological response. That is physical dose distributions and indices can be considered surrogates for interpreting biological response. On the other hand, the results of radiobiological approach followed in some studies in this work is consistent with the dosimetric approach and could well augment the biological response directly, though it suffers from the above limitations.

Thus, in general, this work concludes that intensity-modulation can produce better physical dose distributions for the sites studied. Hence, biological responses which are surrogates for physical doses are expected to improve in IMRT. However, in cervical cancer, this technique can be a potential replacement for a selected group of patients.