ABSTRACT

Cancer is indeed a dreaded disease. Hardly, there is any other malady, which would evoke greater fear and anxiety than cancer and its ranks worst killer next only to heart attack. There are certain fairly reliable method for the alleviation and cure of cancer, particularly, when detected early: viz, surgery, radiotherapy and chemotherapy. More than 60% of cancer patients are treated with radiation therapy, either via solely radiation therapy or combined with other options. Radiotherapy can be delivered in two different forms: external or internal. In internal radiation therapy viz. brachytherapy, encapsulated radioactive sources are placed directly into or adjacent to the tumor. The aim of curative radiation treatment is to deliver dose as high as possible to the tumor without causing unacceptable damage to the surrounding healthy tissues. Hence, the precise estimation of radiation dose is an essential task. The dosimetry nearer to the brachytherapy sources is very difficult to measure experimentally.

In this regard, recently, Monte Carlo based calculations are made feasible to calculate actual dose as well as relative dose distribution. The different Monte Carlo transport codes, which are commonly used by the Medical Physicists include MCNP (Monte Carlo N-Particle), EGS4/EGS_{nrc} (Electron Gamma Shower) and ITS (Integrated Tiger Series). Monte Carlo calculations require very detailed knowledge of the source design to obtain the most accurate results and therefore cannot completely replace careful experimental calculations. In this regard, we intend to use MCNP (version 4B) for the calculation of dosimetric parameters and modelling irregular geometries consisting of a large number of individual volume elements, such as in the case of voxel-based organs. Based on these, the thesis is organized into nine chapters.
The first chapter contains an introduction to radiotherapy and dosimetry. It consists of various types of brachytherapy treatments with regard to the type of implant, duration of implant, method of source loading and dose rate. Physical and mechanical characteristics of some photon emitting brachytherapy sources, important radiation units, various types of radiation dosimetry and dosimeters and interaction of radiation with matter are also dealt with.

The second chapter deals with the history of Monte Carlo technique, brief introduction about various Monte Carlo codes used by the Medical Physicists such as MCNP, EGS4/EGS_{irc} and ITS, history of MCNP code, about the details of using MCNP code and the advantages and limitations of Monte Carlo code.

The third chapter deals with the calculations of the complete set of various basic dosimetric data such as dose rate constant, radial dose function and anisotropy function for the microselectron High Dose Rate (mHDR) Ir-192, Ir-192 seed (Best Industries) and I-125 (model 6711) sources. In this work, MCNP, Monte Carlo code is used to simulate all the data and the results are compared with published results to validate the present study. From this study, it is inferred that the phantom dimensions affect significantly the radial dose function at radial distances near phantom edges. This effect is due to the reduction of scatter contribution to overall dose at the edges of the phantom and it should be taken into account in the case of estimating the dose near body edges.

The fourth chapter is primarily focused on the estimation of relative dose distribution and effective transmission around a shielded vaginal cylinder with Ir-192 source. Commercially available brachytherapy radiation Treatment Planning Systems (TPSs) do not accurately calculate dose
distributions under realistic clinical conditions. In this regard, it was recommended that the effect of heterogeneities and shielding materials should be incorporated in the treatment planning during clinical practice. Based on these, MCNP4B code was used to evaluate the dose distribution around a tungsten shielded vaginal cylinder as a function of thickness and angular shielding. Our computed dose values are in good agreement with that of the reported experimental values.

The fifth chapter deals with the heterogeneities in brachytherapy that arise due to variation in the density of material, size or thickness of heterogeneity and the distance between the source and the point of interest. In this regard, algorithms for accurate dose calculation are required. Based on these, in the present study, an analysis of the effect of inhomogeneities on dose near an Ir-192 gamma ray source is presented. Heterogeneity correction factors (HCFs) are calculated using Monte Carlo method and compared with ion chamber experimental results for different inhomogeneities namely air, PMMA, polystyrene, water, bone, soft tissue and polysulphone, in various phantoms such as in-air, RTPS-PMMA and in-water phantom. Study reveals that the dose correction factor values are ranging from 1% to 40% depending upon the inhomogeneities.

The sixth chapter deals with the construction of Mathematical phantom using MCNP4B and study the brachytherapy dosimetry. The dose distribution at the target as well as surrounding tissues was computed and the results were also compared with that obtained from commercially available TPS. From the study, it is concluded that the patient inhomogeneities may be considered in the brachytherapy TPSs.

The seventh chapter deals with the computation and comparison of the dose distribution around various gold plaque ophthalmic applicators using
Monte Carlo method. The dosimetry of ophthalmic plaques of sizes 12 and 14 mm diameter designed to hold either Ir-192 or I-125 is computed using Monte Carlo code, MCNP4B. The sources of different configurations are introduced in plaque and the Monte Carlo computed dosimetry is compared with that of the reported experimental values for two different radioisotopes such as Ir-192 and I-125. Study indicates that suitable source and plaque dimension may be selected depending on the size of the tumor. For small tumors of sizes less than 1 cm, I-125 may be preferred and for tumors of sizes greater than 1 cm Ir-192 may be used.

The eighth chapter deals with an analysis of Ir-192 source dose distribution using Monte Carlo method and radiochromic film experiment for endovascular brachytherapy. Balloon angioplasty or Percutaneous Transluminal Coronary Angioplasty (PTCA) has been considered as one of the minimally invasive technique to improve the vascular supply to the myocardium. It is found that the use of Ir-192 brachytherapy sources, has led to a significant decrease in the restenosis rate. In this regard, three different source possibilities such as mHDR Ir-192 source with 5 mm, 2.5 mm step sizes and Ir-192 seed source with 1 mm air gap are investigated to obtain uniform radial dose distribution throughout the treatment area. From this study, it is inferred that mHDR Ir-192 source with 2.5 mm step size is effective to get dose uniformity. Further, different restenosis geometries namely linear, dumb bell and hairpin are also simulated with 2.5 mm step size with 15 mHDR Ir-192 sources using Monte Carlo simulation and the results are compared experimentally by using radiochromic films.

The ninth chapter summarizes the overall conclusion of the present thesis work and scope for future work.