ABSTRACT

Stereotactic radiosurgery treatment plan evaluation has been a subject of interest for a long time. Dose-volume histogram is a quantitative tool which determines the plan features such as dose level, dose uniformity and hot or cold spots. Cumulative DVHs particularly in radiosurgery where critical structure proximity and high dose per fraction are involved have proved to be essential in assessment of clinical outcome as described by Kooy. Several authors have compared radiosurgery planning techniques such as arcs, static beams and IMRT based on DVHs. It is concluded that treatment plan generated using intensity-modulated beams appeared superior to multiple isocenter radiosurgery beams for large irregular shaped lesions. Later biological indices such as tumor control probability (TCP) and normal tissue complication probability (NTCP) were calculated from DVHs for treatment technique evaluation. However only limited attempts have been made to correlate the biological modelling with the clinical data. Under these circumstances, the present thesis work focuses on the following:

1. Study on dosimetric parameters of Stereotactic radiosurgery by comparing with Intensity-modulated radiotherapy and Simulation of circular collimator assembly in a conventional 3D planning system.

2. Evaluation of radiosurgery treatment procedures using follow-up data and correlating with tumor control probability in radiobiological modeling.
Based on these, the thesis is organized into seven chapters. As the present thesis work deals with studies on radiosurgery, the first chapter introduces the concept of radiosurgery. The history and evolution of radiosurgery techniques, principles, clinical indications and the equipments used are discussed in detail. Further various processes involved in the treatment planning and quality assurance are explained.

Chapter two discusses multitude of experimental materials used and methods adopted in the comparative analyses of radiosurgery with IMRT and conventional 3D planning systems. Equipments used in the verification of absolute and relative doses in phantom studies are also discussed. Besides the procedures of data collection in the follow-up studies and the estimation of tumor control probability are also described.

Chapter three gives an insight into the dosimetric aspects of stereotactic radiosurgery. Since it is a high-dose per fraction treatment, quality assurance has to be very stringent as the complications increase if the radiation is not focused on target. A hemispherical Perspex phantom was specially designed for dosimetric measurements. Radionics Skull phantom with known geometrical objects was also used for absolute dosimetry. This phantom was used to check the positional accuracy of localization, volume estimation and the dose calculation by the planning system using thermoluminescent dosimeters (TLD). The linearity and sensitivity of the individual chips were studied by exposing them to a range of doses. Relative doses (Isodose distributions) depict the dose fall-off which is critical in Radiosurgery cases. This measurement was done by sandwiching Kodak EDR-2 film in two 5cm Perspex slabs.
To know the isocenter location in the developed film, markers were incorporated in the slabs in longitudinal and lateral axes. The irradiated film was scanned using Vidar Dosimetry Pro scanner and analysed using Scanditronix OmniPro software. The calculated dose pattern from TPS and the measured isodoses from film were visually compared and checked for accuracy. The experimental findings showed good agreement between the two and the results matched the reports in the literature. This is discussed in detail in this chapter.

Chapter four provides study on the treatment planning parameters and the techniques for small intracranial lesions. Six clinical cases planned and treated with Radiosurgery were selected for the study. Histology consisted of 4 meningiomas and 2 acoustic neuromas. These patient data were compared with the results of IMRT.

In this regard, the intensity of individual beamlet is varied and the summation of all beamlets yields a conformal dose distribution. Various parameters such as conformity Index, Homogeneity Index, target volume coverage, non-target tissue and brainstem doses were calculated and compared between IMRT and SRS systems. Patient data were divided into two groups based on the complexity of lesion and the number of isocenters used for Radiosurgery. Analysis was done for each group and for the cumulative data.

Superior conformality and homogeneous dose distribution in IMRT for multiple isocenter cases were also observed. In addition critical structure volume for 50%, 70% and 90% of the prescribed dose in IMRT compared to SRT treatment. However, non-target tissue received significantly higher doses
with IMRT plans. Results show that IMRT treatment modality produces similar results as radiosurgery for small, spherical lesions whereas it is found to be superior to SRS for irregular lesions in terms of critical structure sparing and better dose homogeneity.

The fifth chapter describes the theoretical simulation of radiosurgery planning in a conformal 3D planning system and analysis of dosimetric parameters such as aperture material, source-collimator distance and transmission factor were entered in 3D planning system to make the configuration identical to circular collimators. Radionics Xknife and Helax-TMS were the two treatment planning systems used. Monitor unit calculations, target volume estimations and other planning parameters were calculated and compared. In Xknife DVH is based on the number of calculation points within the external contour of the patient whereas in Helax accuracy of DVH depends on complete coverage of required structures with selected CT slices. Repeated measurements were carried out to ensure the difference arising from the calculation of dosimetric parameters is due to the planning system and not due to the procedure. The study emphasized the fact that though stereotactic localization of the target isocenter is not possible with conventional planning system, there is a feasibility of radiosurgery planning within acceptable limits.

Chapter six gives insight into the follow-up evaluation of the radiosurgery patients treated for benign tumors. Patients who underwent radiosurgery for meningiomas and acoustic neuromas were followed-up with periodic radiological imaging studies. Original radiosurgery volume (cc), prescribed dose (Gy), follow-up period (months) and tumor shrinkage ( %) were statistically analyzed. Correlation analysis was carried out to find the
significance of these factors on treatment outcome. Further, Tumor control probability (TCP), a biological index that evaluates the treatment plan efficacy to produce the desired outcome, was calculated for all these patients using dose-volume histograms. Actual tumor shrinkage observed over a median period of 49 months was used for correlation study with TCP. It was found that the tumor response as observed from serial imaging studies correlated well with biological parameter in most of the cases.

Finally, a brief summary of the work and the future prospects to extend this work in the dosimetric viewpoint are discussed in chapter 7.