Treatment planning strategies for lung injury studies in rat models in 6 MV delivery

Introduction - The radiation treatment of malignant diseases in the lung is limited by radiation tolerance of lung tissue. It has been reported that the lung exhibits complex radiosensitivity patterns that are volume and region dependent. For instance, the base of the lung is more sensitive to irradiation, with increased incidence of radiation pneumonitis and observed bystander response. To explain these phenomena in small animal models, studies in partial lung irradiation are usually done in small animals using kV X-rays and local blocking of the field. These animal models suffer from the fact that they cannot be extrapolated to human systems because of differences in radiation quality and setup accuracy thereby rendering questionable results. In this work, we study three planning strategies using a 6 MV accelerator to achieve optimal partial lung irradiation applicable to studies of regional lung radiosensitivity.

Results - Three different types of plans were designed on CT images of a Sprague Dawley rat model to irradiate 50% of the total lung volume (lung was divided into apex and base) with a prescription dose of 24 Gy to the partial lung. Two VMAT arc therapy plans were optimized to cover to the prescription dose, either the apex or base of the lung. Two AP-PA plans were designed to completely block either apex or base while irradiating the remaining 50% of the lung. Finally, two AP-PA plans were designed to cover, to the prescription dose, the apex or base of the lung. The plans were designed and optimized using the Eclipse AAA algorithm and recalculated using the MMCTP/EGS/Beam Monte Carlo system.

Fig. 1 DVH comparison of AP-PA plans designed to completely block the base or to completely cover the apex. When completely blocking the base the apex will be under dosed, whereas when completely covering the apex by the prescribed dose the base will be partially irradiated.

Fig. 2 DVH comparison of VMAT and AP-PA irradiation of the apex. The VMAT plan leads to a more conformal dose distribution and alleviates the need of using bolus compared to AP-PA delivery.

Conclusions - This work demonstrates the feasibility of dose delivery to small animals such as rats using 6 MV LINAC. Furthermore, it shows that, despite the small size of rat model, the 6 MV VMAT delivery is superior in terms of dose conformality and sparing of the heart and the non-irradiated 50% of the lung compared to the standard, more simple AP-PA delivery. By blocking 50% of lung volume the other 50% of the lung will be under dosed by up to 30%. The AP-PA that covers 50% of the lung by the prescription dose results in over-irradiation of the remaining lung (Fig 2). Accurate dosimetry in small animal studies is essential to render experimental conclusions in these investigations translatable to human studies.