Ruprecht-Karls-Universität Heidelberg
Medizinische Fakultät Mannheim
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Inverse Treatment Planning of Nasopharyngeal Carcinoma in Gamma Knife Radiotherapy

Autor: Manon Spaniol
Institut / Klinik: Klinik für Strahlentherapie und Radioonkologie
Doktorvater: Prof. Dr. F. Giordano

Even though the incidence of nasopharyngeal carcinoma (NPC) is globally low, its location in-between healthy structure represents a challenge for treatment. The main treatment option for this disease is radiotherapy, which thanks to today's advances in imaging and delivery techniques yields satisfying outcomes. Toxicities and recurrences especially inside the high dose regions, however, still occur in patients so that stereotactic deliveries are employed to increase the tumor dose while sparing the surrounding organs at risk (OAR). Radiosurgical devices such as the Leksell Gamma Knife (GK) are known for their sharp dose fall-off outside the tumor region resulting in minimal dose to the healthy brain. Although this device was designed for the treatment of cerebral manifestations, its geometry also allows for therapy of upper spine lesions depending on patients' anatomy. This work aimed at retrospectively evaluating the feasibility of combining primary radiotherapy with linear accelerators (LINACs) and GK as a boost treatment for NPC. In a first part, the newly available inverse treatment planning optimizer for GK was analyzed using retrospective clinical cases. The analysis showed advantages in plan quality especially for the studied benign medical conditions with OAR involvement. Compared to forward planning, tumor coverage was increased by 3.6% and dose gradients were improved (18.1%). Additionally, inverse planning resulted in an important reduction of planning time and low plan variations between different operators. As a second part of this work, a more homogenous prototype version of the optimizer was used to create plans with increased homogeneity in order to spare OAR inside or abutting the tumor. The potential of this prototype version was tested on retrospective cases with OAR involvement and compared to LINAC and clinical GK plans using the current clinical versions of treatment planning systems (TPSs), with the aim of elaborating a homogeneity and OAR sparing range. With the prototype version, two GK plans were generated: one promoted homogeneity while the other aimed at achieving OAR sparing. The results showed that the homogeneity of the prototype plans was improved compared to the clinical GK plans but was still significantly lower than LINAC homogeneity (GK prototype: 14.8%, GK clinical: 25%). The GK plans, however, showed significantly improved dose gradients compared to LINAC plans (GK prototype: 48%, GK clinical: 52%) resulting in OAR dose reduction of at least 6.5%. For tumors with OAR crossing the target volume, the homogenous GK plans showed improved gradients and similar OAR dose compared to the LINAC plans despite higher inhomogeneity. Consequently, with enhanced homogeneity compared to the clinical version, this prototype version can be used for treatment planning of target volumes abutting/comprising OAR such as NPC, which builds the bridge to the last part and goal of this work. With NPC typically involving critical structures such as cranial nerves, osseous and mucous structures, the extent and location of high doses inside the boost volume need to be controlled. LINAC and GK boost plans were calculated using the clinical TPS (Monaco) and the prototype version, respectively. The target homogeneity and OAR sparing was assessed on a restricted retrospective NPC patient cohort due to low incidence and geometrical reasons. The LINAC base plan was summed with either boost plan and resulting OAR doses were compared with the clinical constraints. The LINAC base plans often already exceeded or were very close to clinical planning constraints for some OAR inside the primary PTV, so that adding either boost plan resulted in extensive dose values. With GK boost, however, OAR doses were reduced by up to 36% compared to the LINAC boost and dose gradients were improved. The inhomogeneity with the GK boost was about 20% higher but the location and extent of the hotspots were outside critical regions. Overall, GK boost treatment for NPC following primary radiotherapy with LINACs is feasible and shows dosimetric advantages. Using the possibility of intermediate imaging and plan adaptation, this combination therapy could be used clinically for dose intensification according to OAR constraints.