Ruprecht-Karls-Universität Heidelberg

Medizinische Fakultät Mannheim

Dissertations-Kurzfassung

Entwicklung hocheffizienter Bestrahlungsplanungsansätze für die Volumetrische Intensitätsmodulierte Arc Therapie (VMAT) komplexer Zielvolumina

Development of highly efficient radiotherapy treatment planning approaches for Volumetric Modulated Arc Therapy (VMAT) of complex target paradigms

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Intensity modulated radiation therapy (IMRT) allows high local tumor control with low side effects. It requires, however, more resources than the standard irradiation technique and with the continuous increase of patient numbers, a reduction in treatment time is necessary. In this context, Volumetric Modulated Arc Therapy (VMAT) was introduced and evaluated scientifically regarding plan quality, efficiency and accuracy.
In the *first part* of the thesis, highly efficient planning strategies for complex paradigm treated with the VMAT technique were developed and compared to the current state-of-the-art techniques (3D-CRT, static IMRT, sequential tomotherapy) regarding target coverage, OAR sparing and delivery efficiency. In the *second part*, dosimetrical verifications in order to evaluate the accuracy of the VMAT delivery were performed. Therefore all generated VMAT plans were verified on the linac with phantom verification measurements and the newest digital method with 2D-arrays. The *third part* addresses the important aspect of quality assurance for VMAT. In several tests, the dynamic delivery options of VMAT were analysed and possible critical parameters were identified.
Analysing the planning strategies with dose volume histogram comparisons for all reported paradigms and techniques, the mean target dose was identical for all approaches except for 3D-CRT and the paraspinal tumors were the tolerance dose of an OAR was reached. The modulated techniques show a much higher shielding capacity for OARs than 3D-CRT but as consequence a longer treatment time and number of monitor units. Comparing only the modulated techniques, VMAT showed similar plan quality for all paradigms. The mean homogeneity and conformity over all paradigms were 1.36/1.65 for VMAT and 1.355/1.66 for the best IMRT plan, thus almost being identical. The benefit of VMAT is shown by analysing the delivery efficiency. The number of monitor units for a VMAT plan can be reduced by ~40% when compared to IMRT (mean 524MU vs. mean 850MU) and the treatment time – the most obvious benefit - can be reduced by ~50% (mean 279sec vs. 530sec) across all paradigms and parameters studied in this thesis, with a reduction of ~30% when regarding only the most advanced IMRT- and VMAT-techniques.
The verification measurements using homogeneous RW3 phantoms equipped with radiosensitive films, ionization chambers and 2D-arrays of all VMAT plans showed acceptable results regarding the comparison of calculated and measured dose. The mean absolute deviation measured with an ionisation chamber was -0.99% and the mean 5%/5mm γ-index analysis for films was 94.19%. The high resolution of films and the photon absorption of the film outside the phantoms lead to less agreement than the 2D-array results. Depending on the test setup, they ranged for a 5%/5mm γ-index between 99.76 and 99.94.
The accuracy measurements of the dynamic linac values during VMAT delivery with the build-in recording software of the linear accelerator showed for various deliveries of the same plan high agreement (MLC position and cumulated MU) except for gantry speed. The gantry speed differs from day to day but is compensated by an adaptation of dose rate. The recently implemented newest linac control system allows an additional acceleration as shown by the increased mean gantry speed (0.959

vs. 1.469 degrees per second) of ~50% and leads to a treatment time reduction of nearly 50% as shown in the head and neck verification measurements.
In the context of this thesis, highly efficient radiotherapy treatment planning approaches of complex paradigms using VMAT were experimentally developed and evaluated with verifications measurements of individual VMAT plans. Based on this work, fast deliverable VMAT plans for complex and large paradigms (worldwide first VMAT patient treatment based on Monte Carlo dose calculation) in conjunction with the most recent linac control system (four installations worldwide) could be established successfully in the clinical environment.