Clinical implementation of online MR-guided adaptive radiotherapy for abdominopelvic malignancies

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Purpose/Objective: Online adaptive MR-IGRT was recently implemented at our institution. We report workflow considerations and initial clinical experience with online adaptive MR-IGRT for abdominopelvic malignancies.

Materials and Methods: The first clinically deployed online adaptive MR-IGRT system consists of a split 0.35T MR scanner straddling a ring gantry with three MLC-equipped ¹³⁷Cs heads. The unit is supported by a fast Monte Carlo based treatment planning system allowing real-time adaptive planning with the patient on the table. All patients undergo CT- and MR-simulation for initial treatment planning. A high-resolution volumetric MR image is acquired for each patient at the time of daily treatment setup. Deformable registration is performed using the original simulation CT dataset from initial treatment planning, which allows the transfer of the initial contours and the electron density map to the localization MR of the day. The deformed electron density map is then used to recalculate the original plan on the anatomy of the day for physician evaluation. Physician re-contouring and plan re-optimization are performed when required, and patient-specific quality assurance is performed using an independent Monte Carlo calculation for online adaptive QA. The tool also allows for verification of plan parameters against the original plan.

Results: Online adaptive MR-IGRT was implemented in September of 2014. Five patients with abdominopelvic malignancies have been treated with planned evaluation for treatment adaptation in the first 2 months. The clinical setting included neoadjuvant rectosigmoid (n=3), unresectable gastric, and unresectable pheochromocytoma. MR localization images were used to recalculate dose online for all cases. Re-contouring and re-optimization was deemed necessary for 3/5, while the initial plan deemed sufficient for 2/5 cases. Reasons for plan adaptation included change in target size, weight loss, and change in small bowel anatomy. The approximate times required for online dose calculation, re-contouring, re-optimization, and QA were 2, 15, 2, and 5 minutes, respectively. Treatment utilizing the online adaptive plan was completed successfully for all cases when deemed necessary.

Conclusions: Online adaptive MR-IGRT has been successfully implemented with planning and QA workflow suitable for routine clinical application. Clinical trials are in development to formally evaluate adaptive treatment of bladder, pancreatic, and oligometastatic abdominal malignancies.
was investigated for both sliding window and VMAT techniques (RapidArc™ technology).

Results: Dynalog files permit to predict the number of tolerance faults as a function of the tolerance value, with accurate predictions for low incidences of tolerance faults. All MLCs presented a very similar behavior, with no significant difference between the Millennium120 and the HD120 models. In sliding window techniques the number of beams with an incidence of hold-offs >1% rapidly decreases for a tolerance <1.5 mm. It is to remark that most of the beam hold-offs (>97%) produced in sliding window beams with the 2 mm tolerance were caused by the maximum leaf speed specification not being properly taken into account in the treatment planning process. In VMAT techniques the number of tolerance faults sharply drops for tolerances around 2 mm. For a tolerance of 2.5 mm less than 0.1% of the VMAT arcs presented tolerance faults.

Conclusions: Dynalog analysis provides a feasible method to investigate the optimal tolerance for MLC positioning in dynamic fields. In sliding window treatments the tolerance of 2 mm was found to be adequate. However, to further guarantee the accuracy of treatment delivery, this tolerance could be reduced to 1.5 mm. In VMAT treatments the typically used 5 mm tolerance is excessively high. Instead, a tolerance of 2.5 mm is recommended.

OC-0248
A unifying system for mechanical and (relative) dosimetry quality assurance in radiation therapy
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Purpose/Objective: To replace the multitude of devices with a singular one that measures and records all mechanical, optical and relative dosimetry parameters associated with the monthly quality assurance (QA) of external beam therapy and high dose rate (HDR) brachytherapy systems.

Materials and Methods: The QA system consists of a novel multi-mirror assembly in a light-tight housing which directs images from a receptor plane for capture with an in-line 1.4 mega-pixel CCD camera. The in-line camera simplifies cable management and is shielded against scattered and leakage radiation. The entire housing with the in-line camera is rotated under computer control to any desired position. A single 25 cm x 25 cm phosphor screen is used as the image receptor and is typically positioned at the machine isocenter. Optical images of the room lasers, light field and optical distance indicator are transmitted through the semi-transparent phosphor screen for capture by the camera. The CCD is operated with 0.5 sec integration for optical light imaging. For the QA of external beam radiation, a buildup plate is inserted on top of the phosphor screen which produces a 2D image of an irradiating x-ray or electron field for QA analysis. The CCD is operated with 20 sec integration for radiation imaging, appropriately corrected for dark current background. Relative QA of dosimetry parameters, such as flatness and symmetry, are made with respect to baseline measurements. Beam energy constancy checks were made using brass buildup plates with island filters. For the QA of HDR brachytherapy system, applicators are secured on surface of the phosphor screen where the dwelled positions of source are verified using the resultant fluorescence image.

Results: The system provides high spatial resolution for QA at 0.24 mm x 0.24 mm per pixel. The positioning accuracy of the multi-leaf collimator was determined to be well within 1 mm using the picket fence method. The isocentricities of the collimator and table rotation were determined by the centers of mass (COM) of the resultant images of a small 2 cm x 2 cm rotated x-ray beam. The same COM method was used to determine the gantry radiation isocentricity by rotating the QA system in alignment with the gantry for radiation. The resultant 3D gantry radiation isocenter information cannot be measured with film star-shot. Beam energy constancy based on pixel intensities were within 1% for repeated runs. Planned and delivered dwell positions of HDR sources agreed to 1.2 mm +/- 0.5 mm.

Conclusions: A single device has been successfully developed to unify all mechanical, optical and radiation QA measurements of the accelerator per recommendations of TG-142 of the AAPM. The time spent is reduced by two-third. The system can be applied for HDR source positioning QA. Most important, the system records and documents optical measurements that are now only evaluated visually which will strengthen the confidence for safe patient treatment.

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A multi-institutional study on VMAT delivery accuracy and efficiency for a benchmark plan
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Purpose/Objective: To systematically assess VMAT delivery accuracy and efficiency by means of log file based quality assurance using a dynamic benchmark test plan.

Materials and Methods: The VMAT test plan was generated using iComCAT (Elekta) and delivered at 18 Elekta linacs (13 Synergy with MLCI2, 5 Agility) in Friedrichshafen, Amsterdam, Vienna and Feldkirch. For the test plan, square field shapes with varying field size (0.5x0.5cm² to 24x24cm²) and a full gantry rotation were generated. Control points were...