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Fast, Simple, and Accurate: In Vivo Dosimeter Calibration for HDR/PDR Brachytherapy

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(H&N) plans. A new imaging insert was designed for the phantom to measure set-up error (rotations and translations) with respect to radiation isocenter through automated analysis of portal images acquired during the visit.

Results: Visits were completed at 14 centers with 17 prostate plans created and tested (5 IMRT and 12 VMAT) and 14 H&N plans from Year 1 re-delivered. The average diode pass rate for the prostate plans was higher (96% for 3%/2mm composite analysis) than that of the H&N plans (92.3%) in Year 1, which reflects the different complexity in these sites. Mean pass rate for repeat delivery of the first year H&N plans remained the same but important variations (+/-) were observed at the center level. The program proved to be a useful tool to evaluate impact of practice and infrastructure changes as 7 centers re-computed or re-planned the H&N case to test new practice or equipment. Quantification of phantom set-up error ($n = 17$) showed minimal rotational errors with only one rotational error greater than 0.5°. Translational error was larger, with maximum errors in lateral, vertical and longitudinal directions of 1.7, 1.1 and 2.1 mm respectively, but means of <0.1, 0.3 and 0.1 mm. There was no relationship between pass-rate and magnitude of set-up error.

Conclusions: The CQA program provides a controlled testing environment to assess planning and delivery performance for multiple clinical sites on a variety of planning and delivery platforms. Repeat delivery is a part of the continuous quality improvement loop to assess changes in quality of planning or delivery. Design and integration of a new phantom insert in the program showed that setup errors were small and had limited impact on centers' results. Third year development for the CQA program includes a new clinical site, and introduction of tests to isolate the impact of multileaf collimator calibration on IMRT performance.

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Purpose/Objective(s): In vivo dosimetry (IVD) during brachytherapy (BT) provides with an independent verification of the agreement between planned and delivered treatments. Despite several benefits from real-time IVD, e.g. efficient detection of treatment errors, widespread use of IVD is limited due to factors that compromise the simplicity of the implementation and the dosimetric accuracy. This study presents a fast and accurate calibration procedure for real-time point dosimeters which substantially simplifies clinical implementations of cost efficient and accurate IVD.

Materials/Methods: Impractical and time consuming procedures that involve filling a water tank for dosimeter calibration were avoided by means of a custom made dry calibration phantom that was composed of a 14x14x4 cm3 base piece and a 13x4x30 cm3 tower piece that weighted 2.1 kg. Parallel 1 cm separated inserts in the tower piece for the dosimeter probe and the source catheter provided positional accuracy in lateral directions. The inserts were 15 and 19 cm deep such that the BT source could irradiate at positions below and along the dosimeter probe tip in the longitudinal direction. The dosimeter was calibrated based on its response during a single fly-by BT source scan. The positional accuracy in the longitudinal direction was provided using an iterative algorithm. In each iteration, a chi-square fit between measured and calculated dose rates was performed for candidate relative longitudinal source-to-detector distances. The algorithm updated the longitudinal distance and calibration coefficients in each iteration, and corrected for limited scatter conditions of the calibration phantom, temperature dependence of the detector, and energy dependence of the detector material with respect to water. The final calibration coefficients and energy and temperature corrections were used for fiber-coupled Al_2O_3:C real-time dosimetry during water phantom depth-dose measurements and IVD implementations into the BT treatment workflow.

Results: The calibration was performed in less than 15 minutes including the time required to setup the calibration, power the computer, and run the calibration and iterative algorithm. The water phantom dose rate measurements agreed with AAPM TG43 calculations within 2% for source-to-detector distances between 1.5 and 7.5 cm when energy corrections were made, and within 5% without energy corrections. The calibration procedure was feasible to implement in the clinical routine.

Conclusions: The calibration procedure allows for robust and accurate IVD and a time efficient implementation into the clinical routine. The calibration algorithm corrects for the for energy and temperature dependence of the detector material and can therefore be adapted for any point dosimeter probe intended for real-time IVD during BT.

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VMAT Head and Neck Treatment Delivery: Benchmarking Accuracy of Patient DVH Based QA With Radiological Physics Center (RPC) Head and Neck Phantom Results

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Purpose/Objective(s): The purpose of this study is to a) investigate the accuracy of patient DVH based QA using volumetric measurement guided dose reconstruction (MGDR) for head & neck Volumetric Modulated Arc Therapy (VMAT) delivery by benchmarking against RPC Head and Neck Phantom results, b) investigate the correlation of 3D detector phantom based QA using local gamma and global gamma results when compared against patient DVH based QA.

Materials/Methods: The RPC head and neck phantom was planned and irradiated using 2 arc VMAT delivery method. The results of point doses from RPC TLDs at eight locations and dose profiles from radiochromic film through center of primary PTV inside the phantom were compared against the treatment planning system (TPS) and the results from the MGDR analysis based on 3D detector phantom QA. Also the 3D gamma value was calculated using the MGDR analysis which compares the TPS dose to the predicted dose distribution. Five head and neck patients were planned using VMAT delivery method and the QA was performed using both 3D detector phantom based QA and patient DVH based analysis using MGDR. The correlation between gamma pass rates using both global and local gamma criteria was compared against the gamma pass rates using MGDR analysis.

Results: The ratio of MGDR calculated dose to primary and secondary planning target volume (PTV) compared with both RPC TLD and Eclipse TPS doses was $\leq$ 1.05. The ratio of estimated cord dose from MGDR analysis was $\leq$ 1.09 and 1.03 when compared to RPC TLD and TPS doses respectively. The displacement between calculated dose gradient in the region between primary PTV and organ at risk (OAR) in all 3 planes from MGDR was within 3mm and 1mm when compared to RPC film and TPS profiles respectively. The average 3D local gamma pass rate for the five clinical cases using MGDR was $\geq$ 97.5% and 92% when using 3% 3mm and 2% 2mm analysis criteria respectively. The average gamma pass rate using global gamma 3%3mm criteria was 99.8%, compared to an average local gamma pass rate of 87.1% using 3D detector phantom based QA with a maximum increase of 18%.

Conclusions: Benchmarking the accuracy of patient DVH based QA results to the RPC head and neck phantom established a baseline accuracy and confidence in use of MGDR analysis for VMAT delivery in a realistic patient geometry. For the 5 clinical test cases studied, the low pass rates obtained using the local gamma evaluation criteria in phantom based QA had no significant clinical impact for the patient when evaluated using DVH based QA.

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