Dosimetric verification of TPS, in vivo dosimetry and its clinical implementation

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Purpose/Objective: Verification of the calculated and delivered dose trough independent verification of treatment planning system (TPS) and in vivo dosimetry are important part of the overall radiotherapy quality assurance (QA). The verification of TPS was done according to IAEA recommendations and put an emphasis on dosimetry part of the treatment planning and delivery processes. In vivo dosimetry was implemented as quality assurance procedure for patient treatment verification.
Materials and Methods: Verification of TPS was done with anthropomorphic phantom which was later also used for in vivo measurements prior to patient measurements. Set of clinical test cases suggested by the IAEA, covering a range of typical clinical radiation techniques found in 3D conformal radiotherapy treatment (3D CRT) was used both for TPS and in vivo dosimetry verification. The doses were measured with ion chamber and semiconductor diodes, and compared to doses calculated in TPS for interest points for test cases and points in build up for entrance in vivo readings. Consequently, set of breast patients were checked by in vivo during their regular treatments. For patient treatment verification, tangential half fields were used and in vivo diodes were placed off axis, under large gantry angles, with different wedge types and angles.
Results: The measurements were conducted for 6 MV beam energy and advanced calculation algorithm. The differences between the measured and calculated doses for all test cases were within the tolerance level. The differences of in vivo phantom measurements and TPS calculation varied depending on the test type: 0.5% for open field case to 5.3% for enhanced dynamic wedge (EDW) test case. In vivo measurements conducted for breast patients showed difference of not more than 5% in comparison with values calculated by TPS.
Conclusions: After verification of TPS calculation, dose calibration and correction factors for semiconductor diodes were checked and prediction for in vivo doses in TPS was verified. The errors of 5 % magnitude are common in clinics worldwide and clinical implementation of in vivo dosimetry in our clinic has given confidence that patients are being treated with prescribed dose. This was opportunity to systematically review the uncertainties involved in treatment planning and dose delivery processes leading to more accurate patient treatment.
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What the gamma? The correlation between QA and clinical risk estimates for prostate RapidArc plans

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Purpose/Objective: We investigate how QA criteria relate to sensitivity end specificity for increased normal tissue toxicity risk and risk of decreased tumour control in rotational therapy for prostate cancer.
Materials and Methods: QA analysis for 8 clinical plans and 160 plans with deliberately introduced errors was carried out using ten sets of QA criteria. The tumour control probability (TCP), and risk of rectal bleeding (NTCP_rectum), were calculated. An unacceptable plan was defined as a plan where TCP decreased by more than 2%, or the NTCP increased by more than 50%, as compared with the clinical plan. We chose the 50% NTCP threshold as the rectum was in the low dose region. The sensitivity and specificity for detecting unacceptable plans and their sum (S+S) were determined for each QA criteria set. The diagnostic quality of the QA criteria was also assessed by receiver-operator characteristics curves. For dose difference (DD) = 3 % and distance to agreement (DTA) = 3 mm; the required percentage of gamma smaller than 1 for acceptance (A) was scanned and the value of A which maximised S+S was determined. In an iterative process TCP and TNCP respectively were varied to find the values which corresponded to DD=3%, DTA =3 mm and A = 95 %.
Results: A set of DD = 3 %; DTA = 3 mm and A = 95 % corresponds to ensuring that TCP is > 99 %; and NTCP < 160%; of the clinical values. For DD = 3 %; DTA = 3 mm, S+S was maximised for A = 95 %. We could not identify a single set of QA parameters that was significantly better than the others. However, three of the criteria had a significantly lower area under the ROC curve than the best parameter sets.
Conclusions: A method for relating clinical risk estimates to QA parameters has been demonstrated. This method can be used to determine A for given DD and DTA values once the relative weights of sensitivity and specificity have been chosen by the user. It can also be used to determine which values of ΔTCP and ΔNTCP correspond to the chosen QA criteria set.

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Dosimetric accuracy assessment of a treatment plan verification system for scanned proton beam radiotherapy

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Purpose/Objective: To assess the accuracy of a three-dimensional dose verification technique for patient-specific Quality Assurance (QA) in active scanning proton therapy. Critical cases of major deviations between treatment planning system (TPS) calculated and measured data points are further investigated with Monte Carlo (MC) simulations.
Materials and Methods: Treatment plan verification is performed in a water phantom with the simultaneous use of twelve small-volume ionization chambers (one data set), aligned in four rows in a way that none of them perturbs the other ones. The acceptance threshold is set at 5% for both mean deviation between measured and calculated doses and one standard deviation, over twelve measurement points. Results of 180 data sets, obtained along one year of clinical activity at the Italian National Center for Oncological Hadron Therapy (CNAO), were analyzed.Data were organized based on tumor site (skull versus sacrum) and TPS optimization technique (single field uniform dose SFUD versus intensity modulated particle therapy IMPT). A warning level was defined for data sets showing more than 30% of single point absolute deviations higher than 5% and needing further investigation. A MC tool for plan verification in water was implemented to evaluate the impact of dose calculation, dose delivery and measurement set-up uncertainties on the nine cases resulting out of the warning level.
Results: All patient-specific quality checks resulted within the acceptance threshold. Mean deviation between TPS dose calculation and measurement was less than ±3% in 86%of the cases. For targets located in the skull region an average higher deviation was found, compared to the sacrum region, due to more complex dose patterns involved. In addition, the use of a less robust optimization technique, such as IMPT compared to SFUD, produced much more scattered results and higher single point variation. When all sources of uncertainty were accounted for with the MC tool, all the simulated cases showed even higher level of agreement, with mean absolute deviation ≤ 2% (maximum absolute deviation< 5%).
Conclusions: Along this first year of clinical activity, the results of all patient-specific QA checks performed using ICs in a 3D configuration were found within the acceptance threshold. The use of a MC-based tool to investigate potential causes of major deviations should be further explored, particularly for more complex IMPT plans.

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Optimization of VMAT patient specific QA using ImatriXX 2-D array system and ionometric point dose measurements

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Purpose/Objective: This study was performed to examine the effect of various factors on the optimization of volumetric modulated arc therapy (VMAT) patient specific quality assurance (QA).
Materials and Methods: Plans were created in eclipse treatment planning system (TPS) and measurements were performed in Varian Clinac-iX linear accelerator. Fifteen VMAT Plans were compared on the basis of type of delivery, number of arcs, complexity (treatment site), number of target volumes, and inclusion/exclusion of couch in the plans. For the same cases seven field intensity modulated radiotherapy (IMRT) plans were also created to compare QA results. Planar dose measurements were performed using ImatriXX 2-D array system of IBA dosimetry. Percentage of pixels passed the 3%-3 mm gamma criterion (% dose difference and distance to agreement-DTA) was taken for the comparison. Point dose measurements were also performed and the percentage deviation of the calculated doses versus measured doses was compared. Student'st-test was performed for the statistical analysis of the QA results.
Results: IMRT plans showed better QA results as compared to double-arc plans for head & neck site with more than one target volume (99.6% vs. 97.91% for the mean percentage of pixels passing the set