Commissioning and validation of RayStation treatment planning for TomoTherapy delivery systems

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INTRODUCTION

Until recently, planning for the Accuray TomoTherapy treatment delivery system (TDS) could only be performed using a treatment planning system (TPS) provided by the same vendor. In this paradigm, TPS commissioning and validation was largely vendor-driven, with a universal beam model and well-established tests.[1]

Recently the RaySearch RayStation TPS became the first third-party option to support the Accuray TomoTherapy HDA (or Radixact) TDS. At present, little guidance exists in the field for clinical use of this TPS and TDS pairing. This necessitated development of a commissioning and validation approach that includes consideration of the unique operational characteristics of the TomoTherapy TDS (such as exclusively IMRT delivery, helical geometry, and MLC design).[2]

AIMS

- To convert a "legacy" TomoTherapy system to exclusively RayStation-based TomoTherapy planning **with a clinical downtime of two weeks**
- To create a RayStation beam model, validated using a mixture of point and volumetric detectors, with **measurement approaches consistent with the geometry and delivery modes of the TDS**
- To characterize the TPS/TDS combination sufficiently to ensure **accurate delivery of plans for typical clinical uses**

METHODS

1) Establish the RayStation TomoTherapy HDA beam model
   - TomoTherapy beam modelling begins with a data download from the Accuray database to RayStation. This includes "golden" beam profiles and machine-specific parameters, all either provided or measured by Accuray.
   - The user then specifies overall dose normalization (machine absolute output rate) and jaw-specific relative output factors.
   - The user may optionally modify the energy spectrum and lateral beam profile models; we did not change these from default values for this work.
2) Evaluate delivery accuracy on clinically-relevant treatment plans
   - Ion chamber measurements in the TomoTherapy "Cheese" Phantom with absolute dose calibration
   - Radiochromic film with absolute dose calibration
   - Scandidos Delta4+ volumetric measurements with absolute dose calibration
3) Independently verify dose with an IROC TomoTherapy phantom
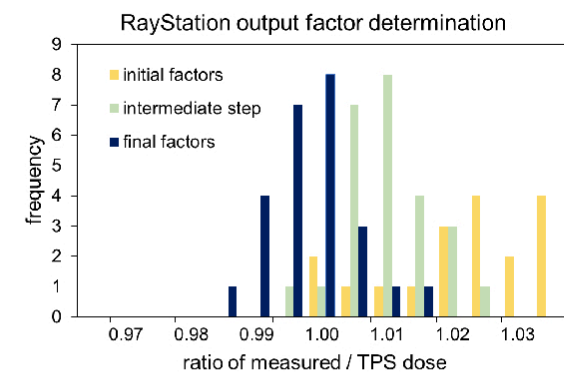4) Analyze ongoing patient-specific quality assurance data

RESULTS

Figure 1: Histograms of measured-to-calculated point dose ratios. Spread in these distributions represents uncertainty or limitations in the model.

Beam model normalization and output factors

Output verification plans delivering uniform dose to cylindrical targets using modulated delivery were created for several permutations of jaw size and delivery mode. These were conceptually similar to "TomoPhant" plans employed for this purpose in the legacy TomoTherapy TPS. These plans were delivered and measured in the Cheese Phantom, resulting in 25 absolute point dose measurements to evaluate against the TPS model. The TPS normalization and output factors were iteratively updated until the distribution of measurement-to-calculated ratios centered about unity across the range of plans (Figure 1). Improvement is observed from the initial results using the default factors (average ratio 1.019) to **the final beam model factors (average ratio 0.996).**

Model utilization and delivery accuracy

Non-modulated fields are not a clinical delivery mode on TomoTherapy systems. Therefore some traditional model verification approaches[3] with these kinds of fields have little practical application here. Instead, **the finalized model was applied to create a set of nineteen IMRT treatment plans representative of the typical clinical utilization of the TDS**. These spanned varying treatment sites, treatment volumes, dose levels, jaw sizes, and delivery modes.

- Using the Cheese Phantom, the average difference between ion chamber absolute point dose measurements and calculated values was 1%, sampled at various points within the treatment volumes (Figure 2).
- Calibrated film measurements on a head and neck, large-field pelvis, and whole brain with hippocampal avoidance gamma analysis[4] with >95% of points passing at 2%/2mm (Figure 2).
- All calibrated Delta4+ measurements passed gamma analysis using institutional IMRT QA standards (3%/3mm), and >50% of measurements passed with stricter (e.g. 2%/2mm) criteria.

Independent, end-to-end testing using the **IROC phantom reported a ratio of measured-to-expected dose of 0.99**.
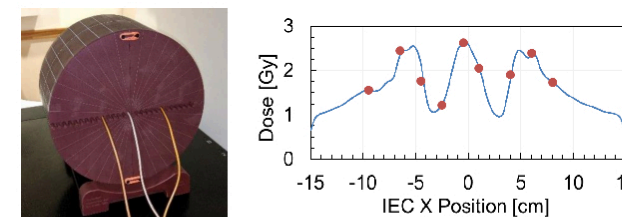

Figure 2: Examples of Cheese Phantom measurements using ion chamber point doses (above) and film (below) for a plan treating the whole brain with hippocampal avoidance and a sub-volume boost. This 1 cm jaw plan is highly modulated and requires a large proportion of small fields and short leaf open times, and therefore represents a stress test at the limits of the beam model and delivery system.
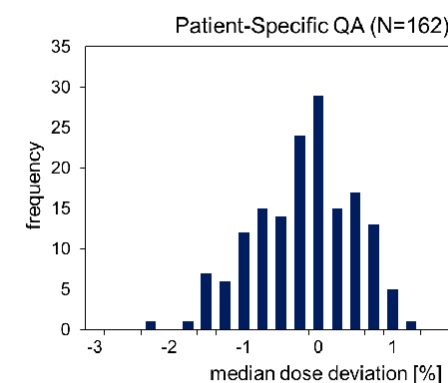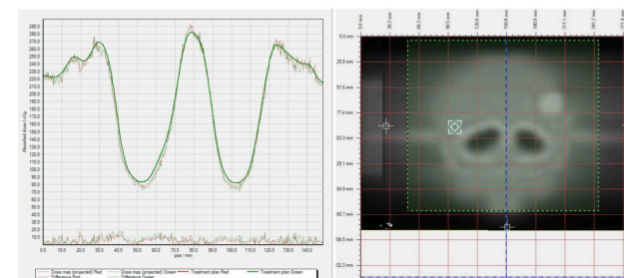

Figure 3: Histogram of median dose deviation for patient-specific QA measurements using the Delta4+ following commissioning. Since machine output was stable over this time, therefore this indicates that the values determined for dose normalization and jaw output factor values were appropriate.

Ongoing patient-specific QA analysis

Given the broad but relatively small sample size of the commissioning measurements for clinical IMRT plans, ongoing analysis of patient-specific delivery quality assurance plans was performed. Of 162 patient plans measured and evaluated since completion of commissioning and clinical release of the system, all have passed institutional IMRT QA metrics (3%/3mm). Similar to the commissioning results, approximately 50% pass at a stricter (2%/2mm) criteria. Spanning all jaw sizes and plan classes, **the average median dose deviation of these measurements was -0.3%** (Figure 3).

CONCLUSIONS

- The RayStation TPS can accurately model a TomoTherapy HDA TDS and is suitable for clinical use in creating and delivering TomoTherapy treatment plans.
- When commissioning a new treatment planning system for a delivery system like TomoTherapy, focus can be shifted from specific concepts such as single field dose profiles and modulated field penumbra agreement to more general and applied metrics such as composite output agreement across delivery modes and planar or volumetric analysis of IMRT delivery.
- Commissioning using this approach (i.e. by delivery of a limited number but broad scope set of clinically-relevant treatment sites and optimization techniques) resulted in a model that was straightforward to create and validate in a short amount of time.
- Ongoing analysis of patient-specific QA has demonstrated that, despite the limited number of validation cases, the beam model is accurate for treatment sites and optimization techniques not explicitly validated during commissioning as evidenced by months of clinical use and quality assurance data.

ACKNOWLEDGEMENTS

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