

The automation of radiotherapy treatment planning assessment

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Aim

The assessment of treatment plans is an important component in the education of radiation therapists. The establishment of a grade for a plan is currently based on a subjective assessment, with the assessor using a pre-determined set of criteria to allocate marks based on a detailed and time-consuming manual review of each student's plan. The automation of this assessment could provide a number of advantages including faster feedback, reduced chance of human error, and simpler aggregation of past results.

Methods and materials

The treatment plans selected for evaluation were planned by a cohort of 27 radiation therapy students enrolled in a second year treatment planning unit. The unit was designed to enable students to:

- utilise planning software to design and optimise dose distributions,
- apply knowledge of dosimetry principles and a critical appraisal of literature in plan evaluation,
- evaluate the importance of normal tissue sensitivity and patient quality of life factors on planning decisions,
- and explain the theoretical basis for planning and evaluation tools and criteria.

The practical assessment of these skills involved the planning of treatments across 5 common tumour sites (for 135 plans in total):

- bladder, with a 64 Gy prescription and dose sparing of the rectum and femoral heads;
- cervix, with a 50.4 Gy prescription and dose sparing of the bladder, rectum and femoral heads;
- larynx, with a 70 Gy prescription and dose sparing of the spinal cord;
- parotid, with 44 and 60 Gy prescriptions and dose sparing of the brainstem, spinal cord and contralateral (left) parotid;
- and prostate, with a 74 Gy prescription and dose sparing of the bladder, rectum and femoral heads.

The treatments were planned using the Pinnacle system (Philips Medical Systems, Madison, USA). To allow more comprehensive feedback for the student work, a single tumour site - the larynx - was selected for marking. The examiner, an experienced radiation therapist, determined optimal beam arrangement parameters in the creation of a clinically acceptable plan. This experimentation informed the assessment criteria for

the treatment, which included evaluations of dose coverage in the target volume and organs-at-risk, as well as aspects of technical competency:

- laser localisation,
- couch removal,
- reference point positioning,
- isocentre positioning,
- number of beams used,
- gantry and collimator positions,
- jaw settings and MLC leakage minimisation,
- the use of wedging,
- and beam weighting.

While the first three of the technical competency criteria are not related to the dosimetric quality of the treatment plan, the selection and optimisation of each of the remaining criteria can have substantial effects on the conformity and homogeneity of the planned dose distribution. Consequently, the calculation of simple metrics describing the degree of normal tissue overdosage or PTV underdosage may provide a shorthand means for grading student work.

To this end, the students' treatment plans were exported using the DICOM framework. The in-house Treatment and Dose Assessor (TADA) software[1] (fig. 1) was evaluated for suitability in assisting with the quantitative assessment of these student plans. Dose volume data was exported in per-student and per-structure data tables, along with dose conformity metrics, dose volume histograms, and reports on naming conventions.

Relationships between the dose conformity metrics calculated by TADA, for the students' treatment plans for the larynx, and the grades assigned to the students based on those plans were examined. The use of the larynx treatment as a representative plan for assessing planning capability was evaluated by comparing grades assigned to the larynx treatment plans with metrics calculated for treatments planned during the same two-week assignment period; the prostate and cervix treatment plans.

Images for this section:

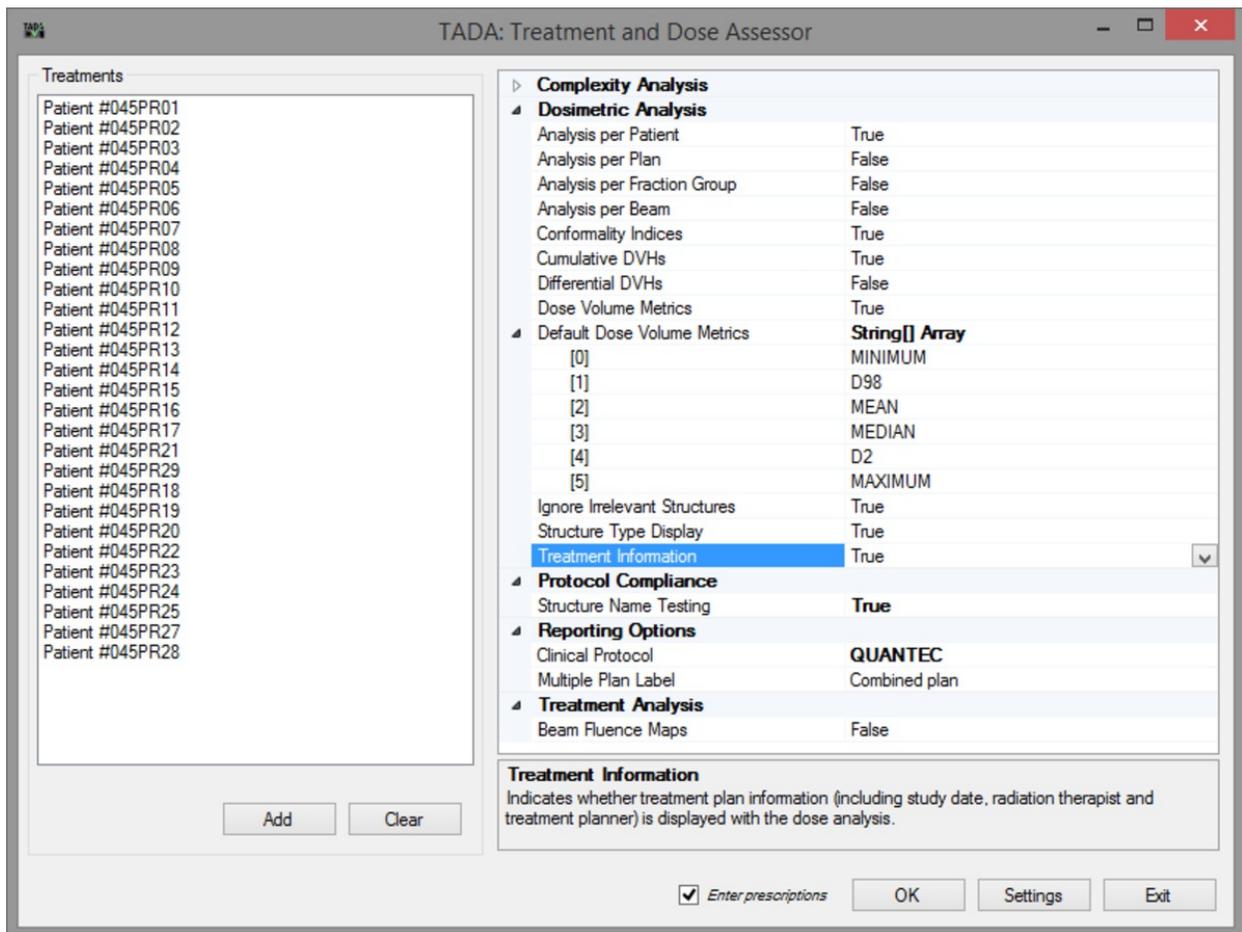


Fig. 1: The TADA software in use.

Results

The manual assessment of 27 larynx treatments planned by radiation therapy students took a total of four days for the examiner to complete: first to develop the assessment criteria, then to mark each plan, go through a moderation process and then to re-evaluate the each plan based on adjustments to the marking criteria from the moderation process. The automated assessment of the same plans using the TADA software took less than two minutes, using a standard desktop PC. Even when allowing several additional hours for examining non-dosimetric parameters such as couch removal and laser localisation and for performing consistency checks or investigating any anomalous results, the use of TADA as a student assessment tool represents a considerable saving of time.

The data aggregated by the TADA software could allow immediate checks of a number of marking objectives:

- the selection of gantry angles (listed with beam names and deliverability metrics);
- the minimisation of MLC interleaf leakage by jaw positioning by the 'mean exposed leaf ratio', a ratio of exposed leaf area to the open jaw area;
- the 95% dose coverage of the PTV by minimum or near minimum dose volume values;
- the maximum point dose;
- and the maximum spinal cord dose.

When comparing the larynx dose conformity metrics evaluated using TADA with the grades assigned to the larynx treatment plans, several trends were observed:

- Plans delivering median PTV doses close to the 70 Gy prescription generally received higher marks than plans delivering median PTV doses 1, 2 or 3 Gy higher than the prescription (fig. 2). (No plans included median PTV doses below 70 Gy.)
- Plans with RTOG conformity indices close to 1.0 (denoting ideal target coverage and conformity) received higher grades than the plans with conformity indices less than 1.0 (denoting underdosage within the PTV) and greater than 1.0 (denoting healthy tissue overdosage) (fig. 3) [2].
- Treatment plan grades were observed to increase with increasing PTV homogeneity, evaluated as the ratio of the PTV volume receiving 95-105% of the prescription to the total PTV volume, for each plan [3].

All of these larynx plans performed well when assessed using the healthy tissue conformity index and healthy tissue overdosage factor [2]:

- The healthy tissue conformity index was greater than 0.6, satisfying Lomax and Scheib's definition of "conformal" [4], in all except one of the plans (fig. 4).
- The healthy tissue overdosage factor was also less than 0.5, indicating that the volume of healthy tissue receiving the prescription dose was less than 50% of the PTV volume, in all except one of the plans (fig. 5).

The evaluation of this range of dose homogeneity and conformity metrics allowed important differences between the properties of the treatments planned for the different anatomical sites to be observed. In particular:

- The PTV doses in the prostate plans were more homogeneous than the PTV doses in the larynx plans:
 - Whereas most of the larynx plans produced coverage homogeneity indices less than 1.0 (indicating that some of the PTV received a dose outside the 95-105% range), all except two of the prostate plans achieved homogeneity indices equal to 1.0.
- The cervix plans were demonstrably less conformal than the larynx and prostate plans:
 - Healthy tissue conformity indices were less than 0.6 in every cervix plan (fig 4), and
 - Healthy tissue overdosage factors were greater than 0.5 in most of the cervix plans (fig 5) and greater than 2.0 in some of the cervix plans (not shown in the figure due to scale).

No statistically significant correlation was found between the assessment results for the larynx plans and the dose metrics for treatments of sites other than the larynx. Similarly, no correlation was found between any dose metric calculated for different anatomical sites. This suggests that using treatments planned for one anatomical site, using one set of guidelines, as an indication of student cohort's ability to plan treatments for other anatomical sites, using other guidelines may be problematic. Specifically, for the students whose work was evaluated in this study, the treatments planned for the larynx were not necessarily representative of the broader quality of each student's work.

Images for this section:

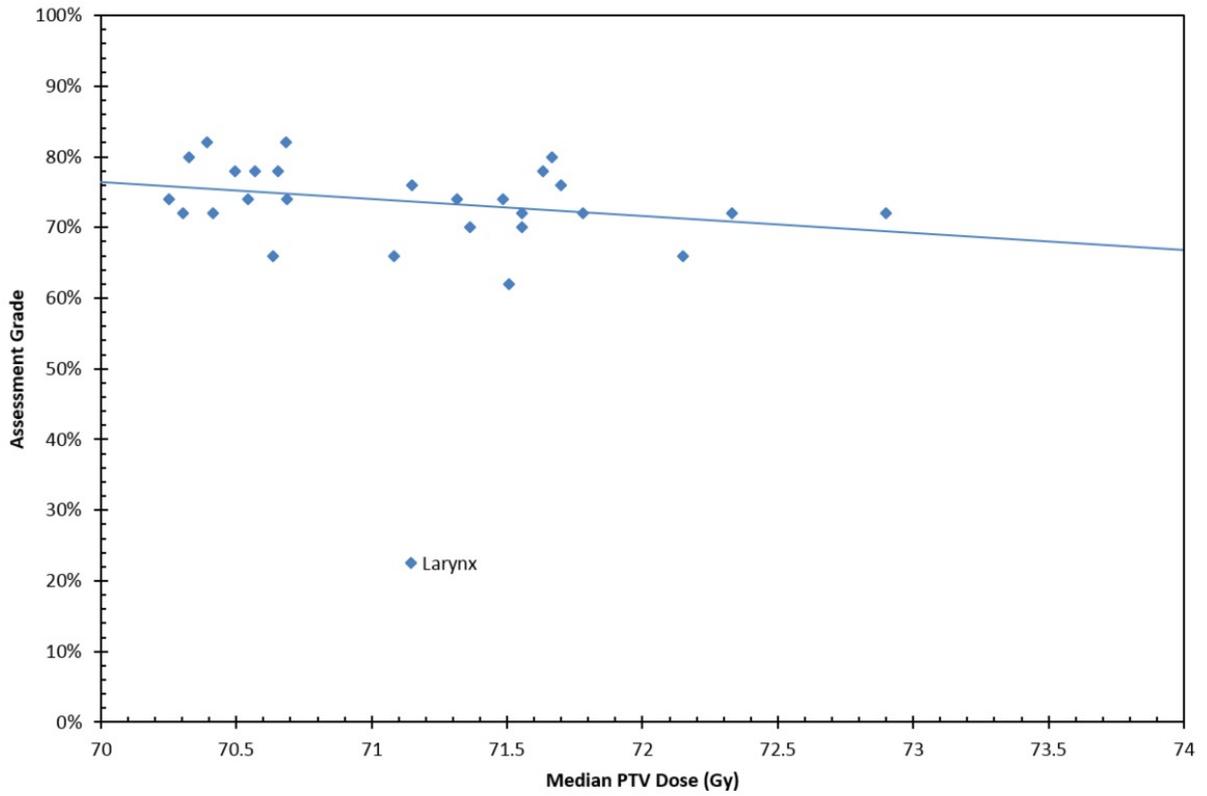


Fig. 2: Relationship between assessment grades and median PTV dose for larynx treatments. (Solid line shows linear fit with free fitting parameters.)

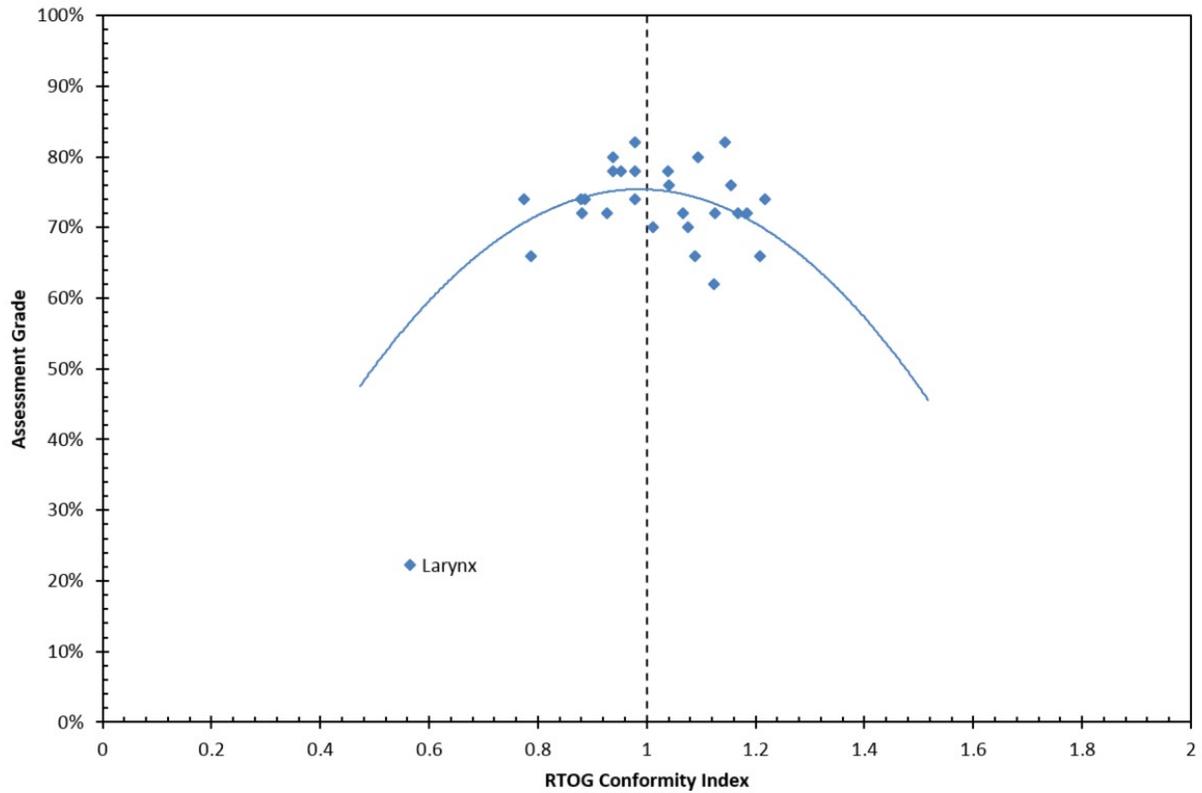


Fig. 3: Relationship between assessment grades and RTOG conformity indices for larynx treatments. (Solid line shows quadratic fit with free fitting parameters.)

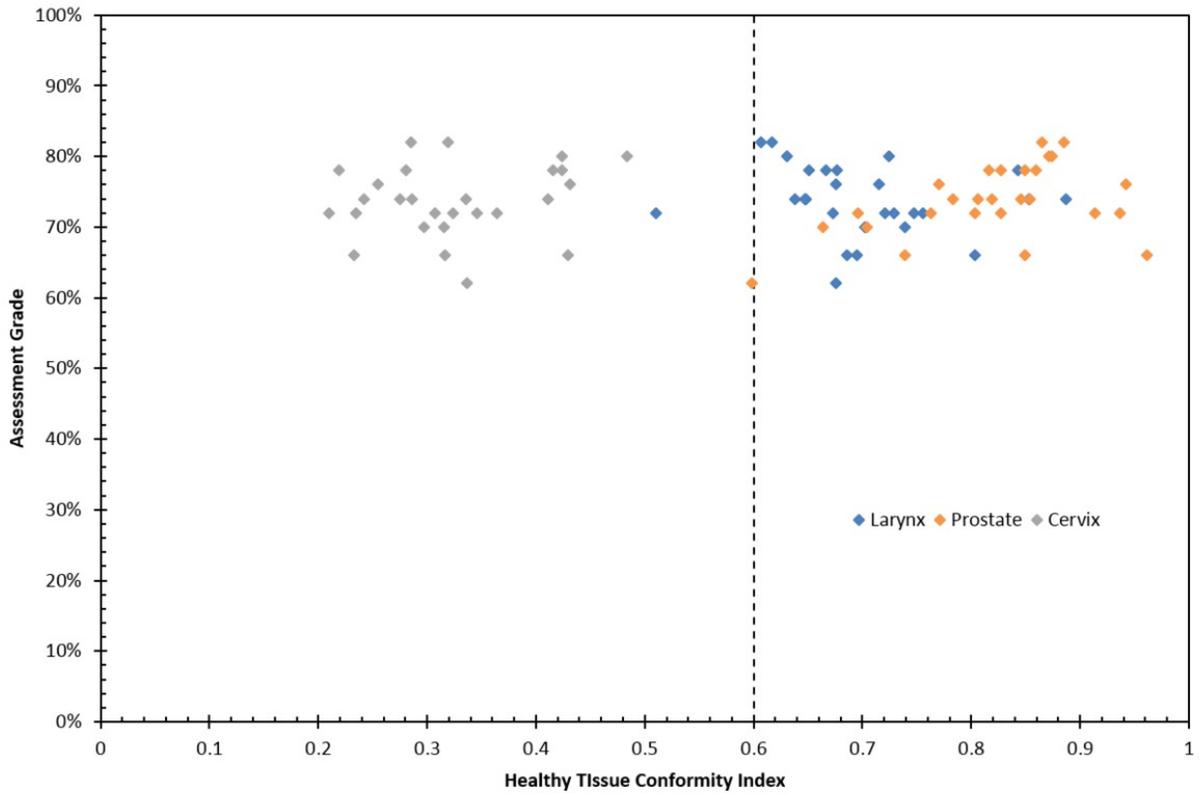


Fig. 4: Relationship between assessment grades and healthy tissue conformity indices for larynx treatments.

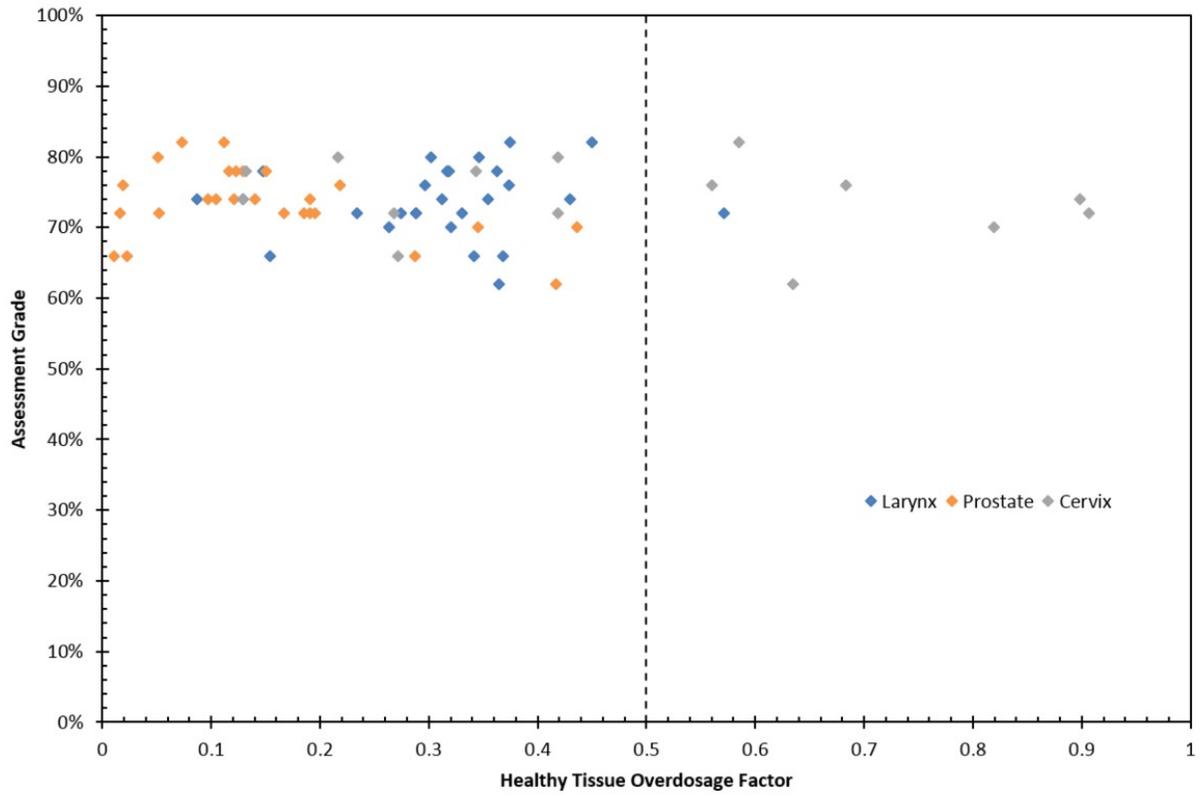


Fig. 5: Relationship between assessment grades and healthy tissue overdosage factor for larynx treatments.

Conclusion

The student treatment plans that were used in this work were initially assessed by teaching staff using a manual process, which is time-consuming and potentially prone to observer error. The TADA software provides examiners with the opportunity to automate part or all of the plan assessment process, potentially reducing the required marking time by a factor of four or more. The data generated using the TADA code could also be used to inform the selection of future assessment criteria, monitor student development over the course, and provide useful feedback to the students. Having a quantitative measure for plans would be a valuable addition to not only radiotherapy education programmes but also for clinical staff development and potentially for treatment credentialing. The new functionality within TADA that was developed for this work could be applied clinically to, for example, evaluate protocol compliance.

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