Trust, but verify – Accuracy of clinical commercial Radiation Treatment Planning Systems

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Abstract

Purpose: Computer based Treatment Planning Systems (TPS) are used worldwide to design and calculate treatment plans for treating radiation therapy patients. TPS are generally well designed and thoroughly tested by their developers and local physicists prior to clinical use. However, the wide-reaching impact of their accuracy warrants ongoing vigilance. This presentation reviews the findings of the Australian national audit system and provides recommendations for checks of TPS.

Methods: The Australian Clinical Dosimetry Service (ACDS) has designed and implemented a national system of audits, currently in a three year test phase. The Level III audits verify the accuracy of a beam model of a facility's TPS through a comparison of measurements with calculation at selected points in an anthropomorphic phantom. The plans are prescribed by the ACDS and all measurement equipment is brought in for independent onsite measurements. In this first version of audits, plans are comparatively simple, involving asymmetric fields, wedges and inhomogeneities.

Results: The ACDS has performed 14 Level III audits to-date. Six audits returned at least one measurement at Action Level, indicating that the measured dose differed more than 3.3% (but less than 5%) from the planned dose. Two audits failed (difference >5%). One fail was caused by a TPS to Record and Verify system transmission error coupled with QA not being performed. The second fail was investigated and reduced to Action Level with the onsite audit team finding phantom setup at treatment a contributing factor. The Action Level results are attributed to small dose calculation deviations within the TPS, which are investigated and corrected by the facilities.

Conclusions: Small deviations exist in clinical TPS which can add up and can combine with output variations to result in unacceptable variations. Ongoing checks and independent audits are warranted.

Purpose

Radiation Therapy relies heavily on computer based Treatment Planning Systems (TPS) to design and calculate treatment plans for most patients treated. Commercial TPS are generally well designed and thoroughly tested by their developers and in the process of approval for general clinical use. Medical Physicists commission and verify the calculations of a TPS before the system is used to plan patient treatments at a Radiation Therapy facility. Medical Physicists also perform ongoing quality assurance (QA) of a TPS and additional checks when updates are installed. However, no check can cover all aspects of the system, and the wide-reaching impact of the accuracy of TPS calculations warrants ongoing vigilance.

The Australian Clinical Dosimetry Service (ACDS) has been created by the Australian federal government as a joint initiative between the Department of Health and Ageing and the Australian Radiation Protection and Nuclear Safety Agency. The ACDS is nearing the end of a three year test period during which it designed and implemented a three level national audit system. Audits are provided free of charge to Radiation Oncology facilities throughout Australia. [Williams et al 2012]

This work reviews findings of the ACDS Level III audit and provides recommendations for checks of TPS.

Methods

The ACDS Level III audit represents an end-to-end test that covers the entire chain of procedures a patient experiences at a Radiation Therapy facility from imaging through planning, checks, setup, delivery and record.

Diagnostic Imaging → 3D Treatment Planning → Patient Setup → Treatment Delivery → Record and Verify

Radiation Therapists conduct each of the steps in keeping with routine clinical practice so that the audit assesses the actual patient process. The treatment plans are prescribed by the ACDS and all measurement equipment is brought in for independent onsite measurements by ACDS auditors. In this first version of audits, plans are comparatively simple, involving asymmetric fields, wedges and inhomogeneities. The audit uses an anthropomorphic thorax phantom (IMRT Phantom Model 002LFC CIRS, Norfolk, VA, USA) which contains material with radiological properties of inhale lung and bone as inhomogeneities (see figure 1).

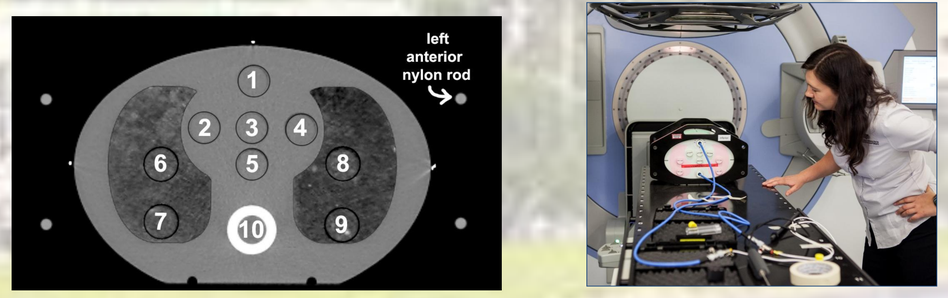


Figure 1: CIRS thorax phantom. CT image and phantom setup for measurement at linear accelerator

The phantom features ten cylindrical ports which, in the default configuration, are filled with solid plugs. For the audit measurements the plugs can be replaced with plugs that hold Farmer type ionization chambers. Three cases are planned and delivered. The audit is exclusively using 6 MV photon beams. The first case is a measurement near linac reference conditions, which serves as a "sanity" check. A standard 10 cm x 10 cm field is delivered using a 100 cm SSD setup with the prescription being in point 1, at 3 cm depth. A second measurement is performed at point 10, which is at 15 cm depth. The chamber is in a water equivalent plug, which is surrounded by a cylindrical shell of bone equivalent material.

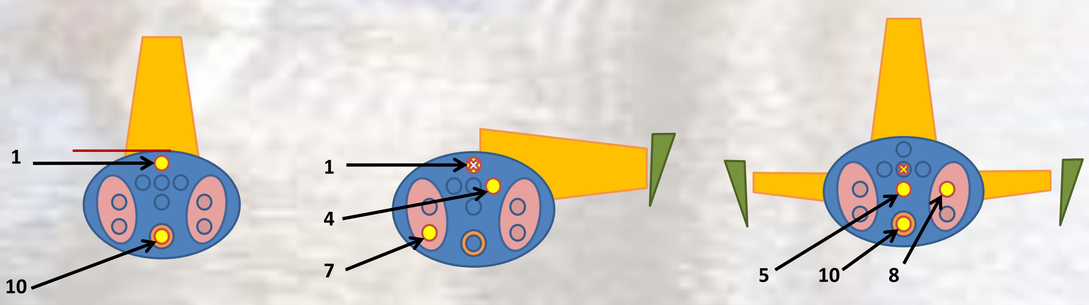


Figure 2: Audit cases for first version of Level III audit. Case 1 is SSD setup, Cases 2 and 3 are isocentric (isocentre marked with cross). Measurement points are indicated with arrows.

Cases 2 and 3 have been adopted from an international test case publication, the IAEA TECDOC 1583 [IAEA-TECDOC-1583]. Small changes were made to the field size to allow for a shorter (superior – inferior direction) version of the phantom, which was easier to transport. Also, in addition to the measurement points suggested in IAEA-TECDOC-1583, additional measurement points were selected. Case 2, which is IAEA-TECDOC-1583 Case 2, uses a lateral wedged field, isocentrically located around point 1, which is also the prescription point. Additional measurement points are in the build-up region behind the lung material (point 4) and at an out of field location in the lung (point 7). Case 3 is based on IAEA-TECDOC-1583 Case 7 with additional measurements taken at points 8 and 10. Measurement points are assessed for each individual beam not the composite. The measure used to compare plan and measurement is "Variation from ACDS", defined as: (facility planned dose – ACDS measured dose) / ACDS measured dose.

Measurement points in low dose areas (outside the field) and points in the lung equivalent material are reported to the facility but not scored (RNS).

A measurement point is considered passed at the "Optimal Level" if the "Variation from ACDS" is within 3.3%. It is considered passed at the "Action Level" if the variation is between 3.3% and 5%. The point is considered at the "Outside Tolerance Level" if the variation is outside 5%. The overall audit outcome is equal to lowest result for an individual measurement point.

Results

The Level III audit was tested in four field trials in February – April 2012. Radiation Oncology Facilities across Australia with a diverse mix of equipment (TPS, Record and Verify System, Linac) were selected for the field trials. All measurement results in the field trials were at "Pass Optimal Level". Feedback from the facilities was incorporated into the procedures and the Level III audit was deployed clinically in July 2012. The ACDS has performed 14 Level III audits to-date. Six audits returned at least one measurement at Action Level, indicating that the measured dose differed more than 3.3% (but less than 5%) from the planned dose. Two audits failed (difference exceeded 5%). In one of the fails an incorrect field size had been transmitted to the Record and Verify system coupled with QA not being performed. The second fail (see data point with +6.9% variation in Figure 3) was investigated and reduced to Action Level with the onsite audit team finding phantom setup at treatment a contributing factor.

Figure 3 shows the results for points 1 and 4 of Case 2. The "Variation from ACDS" is plotted for all audited facilities, including the field trials and one international comparison (random order). As ACDS measured dose is intentionally not corrected for daily output, the latter, as provided by the facility, is also plotted. The first data point is the first above mentioned fail, were the difference for point 4 was > 100% (not shown).

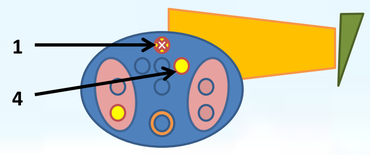


Figure 3: Case 2 results for points 1 and 4

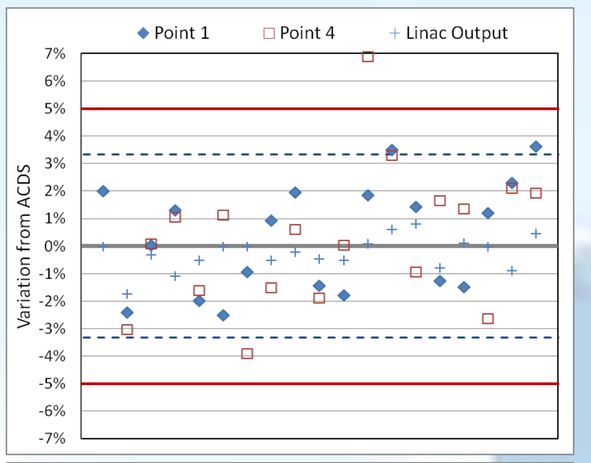


Figure 4 shows the results for the prescription point (Point 5) of Case 3 for all three beams. Linac output is displayed as in Figure 3.

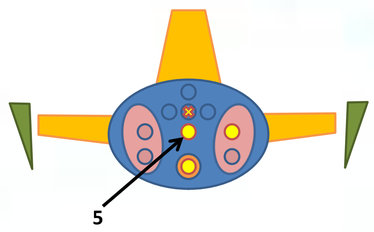
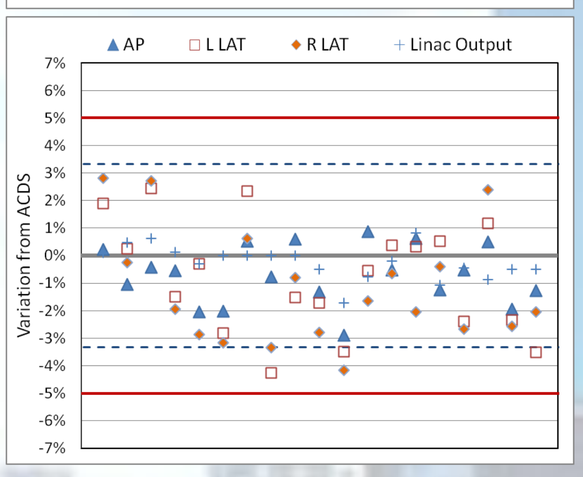


Figure 4: Case 3 results for point 5



Discussion and Conclusions

The Level III audit verifies the accuracy of a beam model of a facility's TPS through comparison of measurements with calculation at selected points in an anthropomorphic phantom. As the audit comprises of several steps, any deviations found could be attributed to several sources. Potentially, errors could also cancel each other out. The treatment plans selected for the audit have been chosen to support troubleshooting of any deviations found. Additionally collected data, such as the complete 3D dose information and radiographic images taken to verify phantom setup at the treatment machine, is available to the audit team in this effort. If further clarification is needed, the ACDS Level II audit can be deployed. The Level II audit uses a synthetic CT data set and a 2D array to verify planar dose delivered to a rectilinear phantom made of water-equivalent material. The cases of the Level II audit represent components of the beams of the Level III audit, helping pinpointing the problem within the TPS or delivery system.

The found Action Level and Fail results are attributed to

1. Not following provided instructions
2. Failing to observe internal protocols and QA procedures
3. Setup errors
4. Dose calculation deviations in the TPS for wedges, in particular for off axis positions
5. Dose calculation deviations in the TPS for Reference conditions.

All of the above can be avoided or rectified. Tests should be implemented to check TPS and delivery system regularly. An independent audit program is warranted.

References

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- IAEA-TECDOC-1583 (2008) Commissioning of radiotherapy treatment planning systems: Testing for typical external beam treatment techniques. International Atomic Energy Agency, Vienna

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Australian Clinical Dosimetry Service
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