Radiation therapists and Level III audits by the Australian Clinical Dosimetry Service

JOERG LEHMANN, JOHN KENNY, JESSICA LYE, TOMAS KRON AND IVAN WILLIAMS, AUSTRALIAN CLINICAL DOSIMETRY SERVICE, AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY

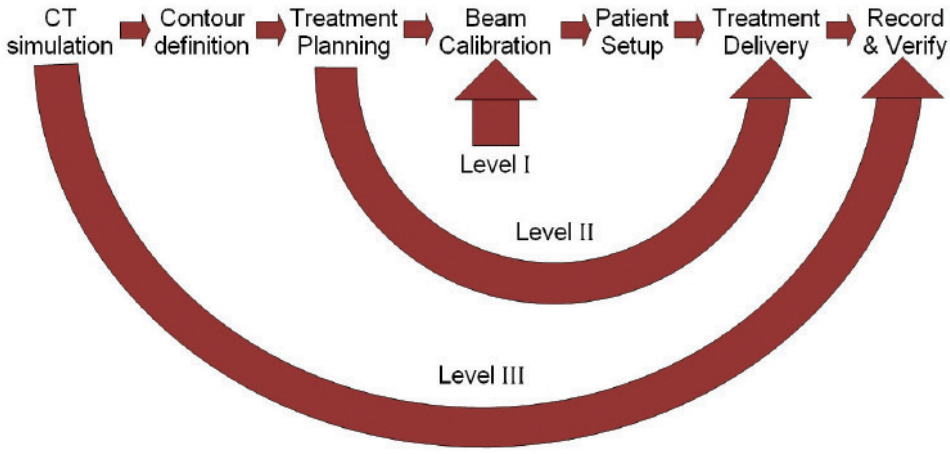

Figure 1: Levels of Audits. Level I: Linac output under reference conditions, Level II: Treatment planning and delivery, Level III: End-to-End test, Based on T Kron, et al.[1]

The purpose of this paper is to describe Level III audits of the Australian Clinical Dosimetry Service (ACDS) and the role radiation therapists have in them.

With the goal of making the auditing process and any needed troubleshooting more efficient; ACDS audits are structured in levels with increasing complexity from point dose verification under reference conditions (Level I) to end-to-end tests (Level III).

In the ACDS Level III audit an anthropomorphic phantom is taken through the complete chain of procedures in a radiation therapy clinic that a patient experiences (CT simulation, 3D planning and treatment, including all quality assurance). Radiation therapists conduct each of these steps in keeping with routine clinical practice so that the audit assesses the actual patient process. The first round of Level III audits test simple plans with open and wedged fields in a thorax phantom.

An ACDS auditor performs measurements during treatment delivery, which are compared with calculations in the treatment plan. All results will be shared with the clinic and the ACDS will provide support should outcomes not fall within the optimal range.

Field trials for the Level III audit process at four facilities throughout Australia have yielded valuable feedback from local staff, in particular from the radiation therapists. The Level III audit was deployed clinically in June 2012.

ADCS Level III audits provide radiation therapists with additional assurance about the accuracy of dose delivery in radiation therapy. Radiation therapists play a critical role in the audits and their active participation is greatly valued.

Introduction

Ensuring that radiotherapy patients receive treatment according to the prescription is an everyday goal of radiation therapists and integral part of their job. The Australian Clinical Dosimetry Service (ACDS) provides an additional layer of reassurance by independently examining clinical dose planning and delivery accuracy through a program of external audits.

The ACDS offers three levels of audits. They are illustrated in Figure 1. A Level I audit checks the output of a clinical linear accelerator under reference conditions. Level II audits verify part of the treatment chain, including treatment planning and delivery. The Level III audit represents an end-to-end test that covers the entire chain of procedures a patient experiences in a radiation therapy facility from imaging through delivery and record.

All audits are confidential. Even the fact that an audit has been performed at a facility is only released with permission of the facility. Most facilities have given this permission. Audit outcomes are only disclosed to the facility and used within the ACDS for analysis and any required reporting to other parts of the government. Summary of nationwide audit results are published by the ACDS in such manner that individual facilities cannot be identified.

Level I audits are generally dealt with by the radiation oncology medical physicists (ROMPs) as they are concerned with how accurately the treatment machine is delivering the intended dose calibration, typically 1.0 cGy/MU to a reference point. Level II audits address the accuracy of two dimensional dose distributions also checking the treatment planning system. They require some help from radiation therapists.

Radiation therapists play a crucial role for meaningful Level III audits. This paper describes the ACDS Level III audits and illustrates how their success depends on radiation therapists.

Audit process

The phantom

The ACDS Level III audit includes the complete chain of procedures in a radiation therapy facility that a patient goes through. As a substitute for the patient the audit uses a humanoid phantom. The phantom (IMRT

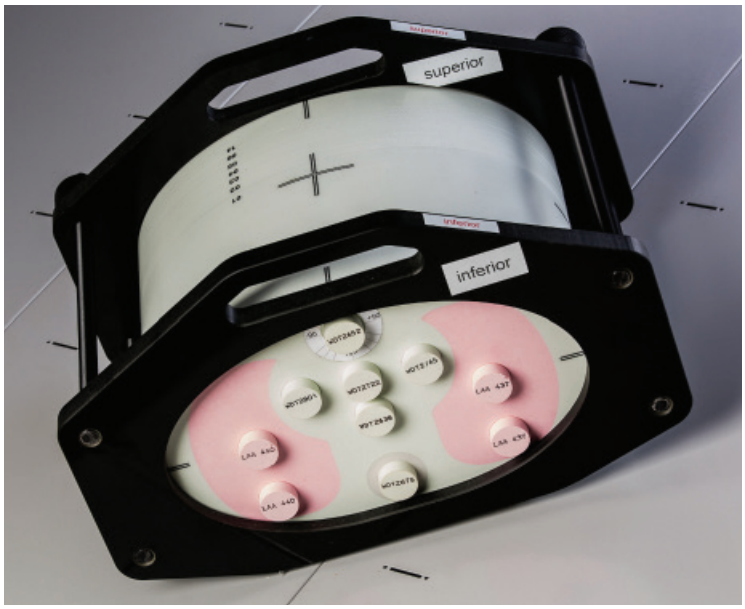

Figure 2: CIRS humanoid phantom roughly approximating the geometry of a human thorax used in the ACDS Level III audit.

Thorax Phantom 002LFC, CIRS, Norfolk, Virginia, USA, Figure 2) roughly approximates the geometry of a human thorax featuring soft tissue, lung and spinal cord, which are made from materials with radiological properties simular to water, exhale lung and cortical bone, respectively.

On the inferior/caudal side the phantom has 10 cylindrical holes, each with a diameter of 2.54 cm and a depth of about 15 cm. In the default configuration the holes are fitted with solid plugs. These plugs can be replaced with customised plugs to place dose measurement devices in the phantom.

Audit format

The ACDS level III audit is generally performed as a two-day visit to a facility by an ACDS auditor or audit team. Day 1 is devoted to phantom imaging, treatment planning and plan quality control. Three simple cases are prepared. The plans are checked by the auditor. On Day 2 the planned treatments are delivered to the phantom several times according to a provided schedule. During the irradiation the auditor performs measurements with detectors placed in the phantom. The measurement results are compared with point doses determined during treatment planning and determine the outcome of the audit. Except for the measurements, all procedures should be performed by staff that would perform them in clinical cases.

Depending on the ACDS schedule, the two audit days might not be consecutive days but have days in between them. All scheduling details are discussed with the facility well in advance and consider the circumstances of a clinical practice.

For some Level III audits, the phantom is sent out to a facility about a week in advance of the ACDS attending the facility. In such cases, it is assumed that all the day 1 activities have been completed and the plans sent electronically to the ACDS prior to the arrival of the ACDS auditor.

CT scanning

The Computed Tomography (CT) scanning of the phantom is performed by a radiation therapist at a CT scanner and with a scanning

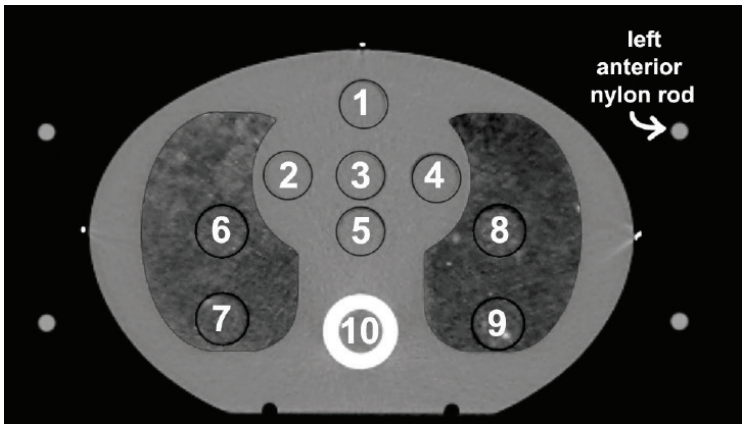

Figure 3: Sample CT scan of the central slice of the phantom with radiographic markers, numbering system for internal rods and the external left anterior nylon rod (LANR).

protocol typically used in the facility for a lung or thorax patient treated with curative intent. The protocol prescribes slice thickness and other machine parameters of the CT scanner. To avoid data connectivity problems sometimes encountered when generic patient demographic data are used, the ADCS provides a set of demographic data, including Patient ID, name, gender, birth date. Using the provided data, which includes the Audit ID as the patient's last name, also facilitates follow up data processing by the ACDS.

The phantom is CT scanned, planned and treated in the supine head first position. The plugs in the phantom are pointed towards the foot of the bed. The phantom is CT scanned in the black carrying frame, including all four threaded nylon rods. Care should be taken to ensure that the phantom is properly held together by the frame prior to scanning. It is also very important that the solids rods on the caudal side the phantom are pushed all the way into their apertures.

Before scanning, radiographic markers should be attached to the cross hair labels on anterior and lateral sides of the phantom. These markers are used to determine the z = 0 slice and its centre in the planning process. If another method is used to determine the z = 0 slice and the isocentre location, the radiographic markers should still be attached for the CT scan, as they are needed for review purposes.

After CT scanning the phantom should be stored in the treatment room or an adjacent room with the same temperature. In the latter case it needs to be brought into the treatment room early on the treatment day (Day 2).

Contouring

After the CT scan, the data should be transferred to the treatment planning system. Structures/regions of interest (ROI) are outlined by a facility planning team member. The structures support the treatment planning, the data analysis and any trouble shooting needed. In addition to typical structures, like lung and spinal cord, there are supportive structures, which need to be density overridden. The latter include the left anterior nylon rod (LANR), which is part of the frame holding the phantom together. The rod will be removed for the treatment as it would be in the way of one of the beams. It therefore needs to be overridden with a zero density in the planning process.

In the central (z = 0) slice, 10 points of interest are marked, one in the centre of each of the 10 internal solid rods. Identifying and marking the centres can be achieved with any available tool, depending on the software. The numbering system for the points is shown in Figure 3.

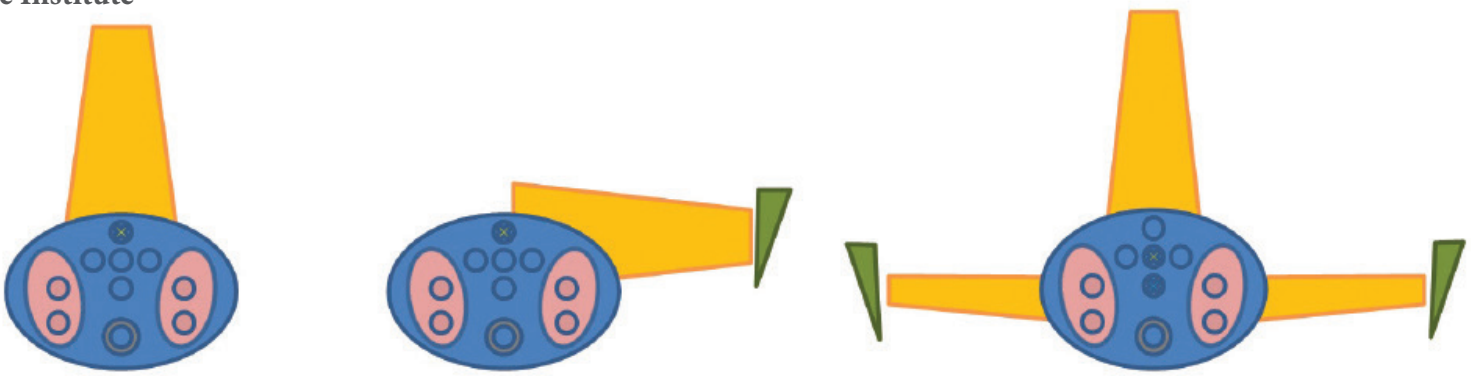

Figure 4: Schematic of treatment cases used in the first round of Level III audits. Case 1 (left) is a SSD setup for a single, open beam. Case 2 (middle) contains a single wedged beam in an isocentric setup. Case 3 (right) is an isocentric three beam plan for a tumour location in the mid thorax. The lateral fields have wedges and are asymmetric with the jaw on the anterior side closed to 0. The anterior beam is open.

The points are used as isocenter points, dose reference points and dose scoring points. Identifying their locations correctly is therefore important for the audit outcome. Radiation doses to these points need to be calculated for each case.

In addition to recording the dose, for points 1–9 the CT number and the relative electron density (RED) or physical density, depending on the planning system, are obtained from the planning system and recorded. The densities are needed to assess the performance of the CT scanner and evaluate the handling of density in the planning system. For the bone equivalent ring around the rod with point 10 the CT number and RED/physical density are determined by sampling 4 locations of the ring (top, left, right, bottom) and averaging the numbers.

Treatment planning

The first round of Level III audits tests two simple one beam plans (one with a wedged field) and a three beam plan for a tumour location in the mid thorax (Figure 4). The cases are based on International Procedures[2] and have been adapted for the ACDS audits.

The field geometry is fully prescribed by the ACDS using the points identified in the previous step. No optimisation is needed. Parameters which are not specified, such as grid size, should be selected as commonly used for a comparable patient case in the facility assuming a radical (curative) intent of the treatment. The treatment plans should be created by clinical staff who would normally work on thorax / lung cancer patient plans.

The treatment plans are reviewed by the auditor as soon as they are done and with sufficient time before the measurements, so that any needed changes can still be made. The plans should be available for review on Day 1 of a two-day audit visit.

Normal facility QA procedures, as performed for a treatment with curative intend, should be followed for checking the cases and preparing them for treatment, including transfers to the Record and Verify System.

With the scheduling function of the record and verify system, each case should be scheduled for treatment five times on the same day. All treatments of the phantom have to be executed in the clinically used mode with the Record and Verify System. Service, Physics or QA modes are not acceptable

At the completion of planning a radiation therapist should verify that the treatment plans can be loaded and treated at the treatment machine by performing a dry run.

Verification imaging

Imaging procedures for patient position verification prior to treatment should be prepared, scheduled and performed for the phantom treatment as they would be for a comparable patient treatment with curative intent. They can vary for the three cases.

In addition to these imaging procedures, the ACDS requests a set of orthogonal MV port films (AP and LAT, 10 x 10 cm^2) for each case to be taken and submitted for review. Reference images (DRRs) are not required by the ACDS but may be needed for acquiring the port films.

Treatment delivery

Preferably two radiation therapists from the facility should be treating the phantom as this is more representative of clinical situations. In case of staff shortage, working with only one radiation therapist is possible. Treatment delivery is generally scheduled several weeks or months in advance and should take place during regular business hours. Reasons for this are not only in the convenience for the staff of the facility but also the accuracy of the audit and the availability of staff with specific skills that may be required e.g. staff with permissions to perform treatment overrides or file exports.

Upon arrival on the day of the measurement, the auditor will immediately bring some of the equipment into the treatment room to join the phantom and to allow it to take on the same temperature.

In addition to radiation measurements, the auditor will also measure air pressure and air temperature. Since the devices used for these measurements are well calibrated, this provides a good opportunity to compare their results with those of the facility used for correction of dose measurement in daily and other regular checks.

For the measurements, the radiation therapists set up and align the phantom on the treatment couch while the auditor prepares the measurement equipment. This involves setting up a laptop computer and a small electrometer in the console area and laying cables from the console (electrometer) into the treatment room.

The radiation dose received at selected points in the phantom is measured using ionisation chambers (detectors). The auditor inserts the detectors into the phantom prior to the irradiation. Some detectors will remain in place for the entire case while others are added after the imaging procedure. For cases 2 and 3 the configuration of the detectors is changed after the treatment has been delivered twice.

The radiation therapists deliver the treatment plans and change the phantom setup for each case as required. The auditor records the measurement results and changes the detector locations. The treatment machine must be operated in the clinically used mode with the Record and Verify System at all times.

For case 3, which uses three beams, the beams must be delivered in the same order as planned in all four (or five) repetitions. While this involves a few more movements of the gantry, than needed with an altered order, it insures the statistics of the measurements to be more accurate.

Additional data and audit results

In addition to the measured radiation dose data and the above mentioned setup verification images, the auditor collects information about the cases which support analysis and any needed trouble shooting. It includes the before described CT number and density measurements for 10 areas and the table used by treatment planning system to convert CT number to density. The latter is provided by the ROMP and the former by the radiation therapist planning the case.

With the help of the ROMP the auditor also collects treatment history information exported from the Record and Verify System, the electronically printed treatment plan information and all three cases DICOM exported from the treatment planning system.

The ACDS compares the measured radiation doses to those in the treatment plan. A report with the results is provided to the clinic.

Preliminary results

The ACDS has tested the Level III audit process in field trials at four facilities in Australia. The facilities were equipped with a range of treatment planning, delivery and record and verify systems.

The phantom was treated successfully in all cases. The dose measurement points that were deemed to be part of the quantitative dose evaluation proved to be reliable while other measurement points (such as those in lung) provide support in trouble shooting as well as opportunity for future applications.

The ACDS has received valuable feedback from the staff at the field trial facilities, in particular from the radiation therapists. The audit procedures and documentation have been updated. The Level III audit was deployed clinically in June 2012.

Discussion

Direct benefits of excellent dosimetry on the clinical outcome of Radiation Therapy treatments have been shown in the literature. Peters, *et al.*[3] brought this well to a point when reporting on outcomes from a multicenter study. They write "These results demonstrate the critical importance of radiotherapy quality on outcome of chemoradiotherapy in head and neck cancer." 3

While inhouse quality measures based on accepted procedures and motivated and trained staff should always be the backbone of excellent radiation oncology treatment planning and delivery, external audits represent an additional essential tool in a quality system.

The ACDS has been created to provide external audits to radiation oncology facilities throughout Australia. The ACDS Level III audit is an end-to-end test evaluating the entire chain of procedures in a radiation therapy facility. Radiation therapists, performing key tasks in these procedures and working daily on the front line of therapy delivery are therefore crucial component in the success of the audit. The audit aims to assess processes as they are in place clinically and help uncover problems that may occur in this highly complex multi-speciality, multi-system and often multi-vendor environment. It is therefore important to conduct treatment planning and delivery for the audit phantom as similarly as possible to a clinical patient case. This calls for an active participation of radiation therapists.

Figure 5: Physicists of the Australian Clinical Dosimetry Service: Ivan Williams, Joerg Lehmann, Jessica Lye, John Kenny.

Conclusion

The Level III audits offered by the ACDS provide radiation therapists with additional assurance regarding the accuracy of dose delivery in radiation therapy. They also give them a mechanism to communicate with and provide feedback to experts from outside their own organisation.

Radiation therapists play a critical role in the audits and their active participation is greatly valued.

Level III audits are especially offered to facilities with new or upgraded systems, but any clinic can access them. There is no charge to the facility for audits by the ACDS as the ACDS is currently in a three year test phase. The future of the ACDS will be decided then based on the experience in the test phase.

Acknowledgements

The Australian Clinical Dosimetry Service is a joint initiative between the Department of Health and Ageing and the Australian Radiation Protection and Nuclear Safety Agency.

References

1 Kron T, Hamilton C, Roff M, Denham J. Dosimetric intercomparison for two Australasian clinical trials using an anthropomorphic phantom. I*nt J Radiat Oncol Biol Phys* 2002; 52: 566–79.

2 Commissioning of radiotherapy treatment planning systems: testing for typical external beam treatment techniques. Report of the Coordinated Research Project (CRP) on Development of Procedures for Quality Assurance of Dosimetry Calculations in Radiotherapy. IAEA-TECDOC-1583, International Atomic Energy Agency, 2008

3 Peters LJ, O'Sullivan B, Giralt J, Fitzgerald TJ, Trotti A, Bernier J, et al. Critical impact of radiotherapy protocol compliance and quality in the treatment of advanced head and neck cancer: Results From TROG 02.02. *J Clin Oncol* 2010; 28 (18): 2996–3002.

4 Comprehensive audits of radiotherapy practices: a tool for quality improvement: Quality Assurance Team for Radiation Oncology (QUATRO) – Vienna: International Atomic Energy Agency, 2007.