



Original Research Article

Auditing local methods for quality assurance in radiotherapy using the same set of predefined treatment plans



Enrica Seravalli^a, Antonetta C. Houweling^a, Leo Van Battum^b, Thom A. Raaben^c, Marc Kuik^d, Jacco A. de Pooter^e, Marion P.R. Van Gellekom^f, Jochem Kaas^g, Wilfred de Vries^a, Erik A. Loeff^h, Jeroen B. Van de Kamer^{g,*}

^a Department of Radiation Oncology, University Medical Center Utrecht, Utrecht, The Netherlands

^b Department of Radiation Oncology, VU University Medical Center, Amsterdam, The Netherlands

^c Medisch Spectrum Twente, Enschede, The Netherlands

^d Department of Radiotherapy, Noordwest Ziekenhuisgroep, Alkmaar, The Netherlands

^e Department of R&D VSL, Delft, The Netherlands

^f Department of Medical Physics, Radiotherapiegroep, Arnhem, The Netherlands

^g Department of Radiation Oncology, The Netherlands Cancer Institute, Amsterdam, The Netherlands

^h Department of Radiation Oncology, Erasmus MC-Cancer Institute, Rotterdam, The Netherlands

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ABSTRACT

Background and purpose: Local implementation of plan-specific quality assurance (QA) methods for intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) treatment plans may vary because of dissimilarities in procedures, equipment and software. The purpose of this work is detecting possible differences between local QA findings and those of an audit, using the same set of treatment plans.

Methods: A pre-defined set of clinical plans was devised and imported in the participating institute's treatment planning system for dose computation. The dose distribution was measured using an ionisation chamber, radiochromic film and an ionisation chamber array. The centres performed their own QA, which was compared to the audit findings. The agreement/disagreement between the audit and the institute QA results were assessed along with the differences between the dose distributions measured by the audit team and computed by the institute.

Results: For the majority of the cases the results of the audit were in agreement with the institute QA findings: ionisation chamber: 92%, array: 88%, film: 76% of the total measurements. In only a few of these cases the evaluated measurements failed for both: ionisation chamber: 2%, array: 4%, film: 0% of the total measurements.

Conclusion: Using predefined treatment plans, we found that in approximately 80% of the evaluated measurements the results of local QA of IMRT and VMAT plans were in line with the findings of the audit. However, the percentage of agreement/disagreement depended on the characteristics of the measurement equipment used and on the analysis metric.

1. Introduction

Intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) techniques have become standard practice in radiotherapy. Given the complexity of these delivery methods, the dose delivery needs to be verified against calculation by the treatment planning system (TPS) [1].

Several reports have been written regarding recommendations on quality assurance (QA) for IMRT and VMAT plans [1–5]. Still, local implementations of plan-specific QA methods may vary because of

differences in hardware, software and evaluation metric. To ensure independent verification of plan-specific QA, many dosimetry audits have been conducted using locally devised treatment plans [4,6–15]. Since the local QA equipment is also used to devise the local class solution, such audits may not give insight in its ability to detect non-conformities for plans not belonging to the original class solution. Since over time, treatment plans may deviate unnoticed from the intended class solution it is important to determine whether local QA systems can detect errors for plans not belonging to the class solution. To achieve this aim we distributed a limited set of pre-defined treatment plans

* Corresponding author.

E-mail address: j.vd.kamer@nki.nl (J.B. Van de Kamer).

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using the radiotherapy (RT) extension to the Digital Imaging and Communications in Medicine (DICOM) standard among the participating institutes. Using the same set of treatment plans allows the comparison between the local QA and the audit findings of different centres.

2. Materials and methods

The audit was performed at all 21 Dutch radiotherapy centres extended with one satellite location. Due to the lack of plan import options in the treatment planning software, in 3 of 22 sites plans had to be generated by the institute itself. The results of these measurements were not included in the analysis.

2.1. Treatment plans

Treatment plans of different complexity were generated: simple (cervix) and complex (head and neck) IMRT and VMAT, and a stereotactic (brain) VMAT plan. The audit plans reflect typical clinical IMRT and VMAT delivery, selectively chosen such that all delivery parameters were valid for the various combinations of TPS and linac delivery system used by the participating centres, provided that particular treatment technique was used clinically. For comparative and logistical reasons, the audit was performed for 6 MV beams only. Based on the occurrence of linac and TPS (Table 1), two plan sets were created: one for Elekta (Elekta Instrument AB, Stockholm, Sweden) linacs, devised in Pinnacle (Philips Medical Systems International B.V., Best, the Netherlands) and one for Varian linacs, devised in Eclipse (Varian Medical Systems, Palo Alto, California). We strived to keep the planning parameters as similar as possible (Table 2). The IMRT plans designed for the Elekta linac used a step-and-shoot technique, whereas all other plans used a sliding-window technique.

To assess the complexity of the plans, the segment shape, leaf motion and dose distribution were evaluated visually. To ensure accurate dose measurements in the audit phantom, the isocentre was located in a homogeneous high dose region. The linacs were grouped into two types:

- Standard: Elekta MLCi(2) or Varian Clinac
- Advanced: Elekta Agility or Varian TrueBeam

Whenever possible, the simple plans were delivered on a standard linac, the complex and stereotactic plans on an advanced one. For the Varian linacs, the same treatment plans could be delivered on both linac types, whereas the standard and advanced Elekta linacs are not interchangeable due to differences in head design (e.g. multi-leaf collimator (MLC) and block design). Besides the differences in head design, there was also a variation in availability of linac options (i.e. not all institutes purchased the VMAT license on Elekta MLCi(2) linacs).

2.2. Audit preparation

The treatment plans, audit phantom Computer Tomography (CT) scan, structure data set and the audit preparation manual were

distributed to all institutes. The institutes calculated the dose on a $2 \times 2 \times 2 \text{ mm}^3$ grid, using for the phantom a relative electron density of 1.016 g/cm^3 or mass density of 1.04 g/cm^3 [16]. All other calculation settings, such as dose algorithm, correction for treatment table were according to the clinical protocol of the institute.

The institutes performed their own QA measurements in advance using their local equipment (Table 3) and analysed the measurements according to the audit criteria (Section 2.3).

2.2.1. Measurement equipment

All measurements and irradiation of calibration films for the audit were performed using the OCTAVIUS® II (PTW Freiburg GmbH, Freiburg, Germany) phantom and its associated inserts for the three different dosimeters: ionisation chamber for an absolute dose measurement, ionisation chamber array for a 2D measurement with high reproducibility [11,17], and radiochromic film for a 2D measurement with high resolution. The ionisation chamber was calibrated by the Dutch Metrology laboratory, VSL; the 2D array was calibrated by its manufacturer (PTW Freiburg GmbH, Freiburg, Germany) and checked for constancy at the Netherlands Cancer Institute – Antoni van Leeuwenhoek.

2.2.1.1. Audit ionisation chamber. The point dose was measured using a 0.016 cm^3 PinPoint ionisation chamber (TN31016 PTW Freiburg GmbH, Freiburg, Germany) in combination with an electrometer (Unidos^{Webline}, PTW Freiburg GmbH, Freiburg, Germany). The readings were converted to absolute dose according to the k_Q formalism [18].

2.2.1.2. Audit array. The OCTAVIUS® II with 729 plane-parallel ionisation chambers was used for the array measurements and the readings were recorded by the VeriSoft software (VeriSoft®, version 6.1, PTW Freiburg GmbH, Freiburg, Germany [19]). To compensate for daily output variations, the dose measured for a $10 \times 10 \text{ cm}^2$ field by the central ionisation chamber of the array was used for normalisation.

2.2.1.3. Audit film. Film measurements were performed using radiochromic films (Gafchromic EBT3, Ashland Specialty Group, Wayne USA) from a single batch. For absolute dose calibration using three colour channels [20], quarters of a film were irradiated in the audit array with 0, 200, 400 and 600 MU ($\sim 0\text{--}3.8 \text{ Gy}$) with a $10 \times 10 \text{ cm}^2$ field. The films were converted to dose according to the well-established local protocol of the VU University Medical Centre (Amsterdam, the Netherlands) [21,22].

2.3. Analysis

2.3.1. Ionisation chamber

The relative difference between the dose as calculated by the local TPS and the audit measurement corrected for daily accelerator output variation was defined as Δ_N . Δ_N was calculated by multiplying for each plan the relative difference between the local TPS calculated dose and the audit measurement, with the ratio of the local TPS calculated dose and the audit measured dose for the $10 \times 10 \text{ cm}^2$ field in the

Table 1

Available linac vendor and TPS combinations in the Netherlands at the time of the audit measurements (October 2014 - August 2015).

Linac vendor	TPS system	Number of institutes	RTP import
Elekta	Monaco (Elekta Instrument AB, Stockholm, Sweden)	2	Not possible*
Elekta	Oncentra (Elekta Instrument AB, Stockholm, Sweden)	2	DICOM
Elekta	Pinnacle (Philips Medical Systems International B.V., Best, the Netherlands)	10	Pinnacle file format
Elekta	Raystation (RaySearch, Stockholm, Sweden)	1	DICOM
Varian	Eclipse (Varian Medical Systems, Palo Alto, California)	5	DICOM
Varian	iPlan (BrainLab AB, Munich, Germany)	1	Not possible

* Limited DICOM import is possible from version 5.1 but not for externally generated phantom plans.

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