Physica Medica 30 (2014) 96–103

Contents lists available at SciVerse ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

Treatment planning systems dosimetry auditing project in Portugal

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ARTICLE INFO

Article history:
Received 7 February 2013
Received in revised form
22 March 2013
Accepted 27 March 2013
Available online 23 April 2013

Keywords:
Treatment planning systems
Dosimetry audit
Dose calculation algorithms

ABSTRACT

Background and purpose: The Medical Physics Division of the Portuguese Physics Society (DFM_SPF) in collaboration with the IAEA, carried out a national auditing project in radiotherapy, between September 2011 and April 2012. The objective of this audit was to ensure the optimal usage of treatment planning systems. The national results are presented in this paper.
Material and methods: The audit methodology simulated all steps of external beam radiotherapy workflow, from image acquisition to treatment planning and dose delivery. A thorax CIRS phantom lend by IAEA was used in 8 planning test-cases for photon beams corresponding to 15 measuring points (33 point dose results, including individual fields in multi-field test cases and 5 sum results) in different phantom materials covering a set of typical clinical delivery techniques in 3D Conformal Radiotherapy.
Results: All 24 radiotherapy centers in Portugal have participated. 50 photon beams with energies 4–18 MV have been audited using 25 linear accelerators and 32 calculation algorithms.
In general a very good consistency was observed for the same type of algorithm in all centres and for each beam quality.

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http://dx.doi.org/10.1016/j.ejmp.2013.03.008

Conclusions: The overall results confirmed that the national status of TPS calculations and dose delivery for 3D conformal radiotherapy is generally acceptable with no major causes for concern. This project contributed to the strengthening of the cooperation between the centres and professionals, paving the way to further national collaborations.

Introduction

According to accident and incident international reporting databases in radiotherapy, treatment planning system (TPS) related occurrences are among the main sources of errors [1].

In line with its long history in dosimetry auditing, the International Atomic Energy Agency (IAEA) promoted the present project on TPS audit with the purpose of ensuring improved and safer practices in radiotherapy.

The details of the project design were published by the IAEA. The comprehensive IAEA document on acceptance testing, commissioning and QA of TPSs, published as Technical Reports Series No. 430 [2], was further focused on dose computation verification tests to meet the practical needs of common users namely in small hospitals with reduced staff [3].

In the present version the test-cases cover a range of typical delivery techniques in three-dimensional conformal radiotherapy (3D-CRT) with photon beams that have been chosen for TPS commissioning according to the recommendations of IAEA.

After a pilot study to test the audit design [4], the Baltic States, Hungary, Serbia [5], Slovakia and Poland have conducted national TPS audits with the IAEA assistance, before Portugal has done it [6].

The adopted methodology uses an anthropomorphic phantom – CIRS thorax 002 LFC (CIRS Inc., Norfolk, Virginia) – and follows the radiation treatment sequential steps from image acquisition to treatment delivery, including image transfer and planning process, in an end-to-end approach.

According to the proposed methodology the DFM_SPF was recognized as the national auditing organization in Portugal. The national coordinator traveled through all 24 RT centres with the phantom to carry out the audit between November 2011 and April 2012.

The project implementation phases included: i) Individual centres application in a volunteer basis – September and October 2011; ii) First round of the audit through the 24 participating centres: performance of two phantom scans (the first one for CT to RED (relative electron density) conversion purposes and the second one for planning the test cases) – November and December 2011; iii) Second round of the audit: performance of the audit measurements in each centre after that centre had calculated the test cases plans for the different energies and algorithms used in its clinical practice – January – March 2012. The irradiation of the test cases started with a dose intercomparison between the dosimetric reference system of the pilot centre and the local one; iv) Finally the evaluation workshop took place in June for the presentation of the national results and global discussion.

Materials and methods

National characterization

Portugal is the westernmost country in Europe and includes also as national territory the Atlantic archipelagos of the Azores and Madeira. The present population is around 10.5 million, oddly distributed among the 18 administrative districts [7]. In fact, if we add to the two more important metropolitan areas of Lisbon and Porto four other western coast districts we will sum up almost 70% of the population. In both insular territories there are less than 0.5 million people. In terms of radiotherapy health care, the recommended ratio of 5–6 linear accelerators per million inhabitants would imply an installed park of around 60 treatment units.

As of April 2012, there were 44 linear accelerators installed in Portugal, including 2 units in Madeira and none in Azores. They pertain to 24 radiotherapy centres. 8 out of these 24 centres are public hospitals and own 18 of these linacs. The other 16 are private RT centres with one or two machines, each owning the remaining 26 treatment units. The installed treatment units park covers more than 70% of the national needs but the geographical distribution is not optimal [8]. During the audit project a questionnaire also proposed by the IAEA was answered by all RT centres about the typical characteristics of RT treatments and we concluded that at present more than 80% of the radiotherapy treatments offered to patients in Portugal can be classified as 3D-CRT treatments.

All 24 RT centres have volunteered to participate in the audit project. Due to logistic reasons it was decided that just one linear accelerator would be involved in the audit in each centre. The total number of linear accelerators used in the audit was 25 out of 44 because in one centre 2 linacs have been used. From the 25 linacs used in the audit, 15 are Varian machines, 6 Elekta and 4 Siemens. More than 90% of the linacs are less than 10 years old. The oldest unit was installed in the year 2000.

The 25 linacs corresponded to 50 high energy photon beams distributed as follows according to the nominal energy: 4 MV(1); 6 MV(24); 10 MV(6); 15 MV(14); 16 MV(2) and 18 MV(3). Just photon energies have been tested in the audit.

25 TPSs have been audited grouped from three main commercial names: 14 Eclipse (Varian); 9 XiO (CMS/Elekta) and 2 Oncentra (Nucletron/Elekta), corresponding to 32 tested algorithms. They have been grouped according to broad types for volume scatter integration and heterogeneity modeling without the reference to the particular version in each case. Thus we have labeled PB (Pencil Beam) those models that ignore the lateral transport of electrons and where inhomogeneity corrections are primarily based on the equivalent path length. Two TPSs have this kind of algorithm – Eclipse (from Varian) in 9 of the participating centres and Oncentra (from Nucletron/Elekta) in 2 centres. The other algorithms – Analytic Anisotropic Algorithm, AAA (in Eclipse) in 9 centres; Superposition and Fast Superposition (in XiO/Elekta) in 7 centres and Collapsed Cone, CC (in Oncentra) in 1 centre – correspond to models that in some extent incorporate the lateral transport of electrons. These two kinds of models will be further referred in this work as Type A and Type B algorithms, respectively, following the terminology used in Ref. [9].

Audit phases

Pilot centre audit

The pilot centre was audited with the presence of the IAEA expert. Two scans of the CIRS phantom have been done in the local CT-scanner (Somaton Sensation Open, from Siemens), according to the IAEA methodology. After the planning of the 8 test cases, the corresponding irradiations for 6 and 15 MV in an Oncor Avant-Garde from Siemens linac have been performed.

Before the irradiations, a dose comparison has been done between the IAEA calibrated ionization chamber and the local