Formulation and initial experience on patient specific quality assurance for clinical implementation of dynamic IMRT.

K.Krishnamurthy, S.S.Sivakumar, C.A.Davis, R.Ravichandran, Kamal El Ghamrawy

Department of Radiotherapy, National Oncology Center,
Royal Hospital, Muscat, Sultanate of Oman

Abstract

Intensity modulated radiotherapy (IMRT) is an advanced form of 3D conformal radiotherapy combining several intensity modulated beams to deliver the prescribed dose to the target with precision, sparing the adjacent normal tissue structures. The complex nature of IMRT delivery needs a precise patient specific quality assurance (QA), proper verification of dosimetry and treatment. QA procedures are important measures to ensure that the treatment can be delivered according to the treatment plan. In this report, we are presenting a formulation of a proposed protocol and results of patient specific QA carried on two IMRT plans. The QA consists of an absolute dosimetry, film dosimetry and dynalog files verification of treatment plans. The absolute doses, planar and fluence doses calculated by the TPS are compared with the measured values. The dynalog files recorded during the treatment delivery of two plans were analysed. The measured error in absolute dose is <3% in both the plans. An average of >98% of counts are having <0.1cm errors in dMLC positions. The average RMS value of leaf motions is <0.05cm in both the cases. The errors in film dosimetry are <3%. All the results obtained are comparable to the standard values and well within the acceptable limits. The paper outlines the minimum procedures required for the patient specific QA measurements for the clinical implementation of IMRT. The measurements help to understand and confirm the accuracy of IMRT delivery system.

Key words

Absolute dose, Relative dose, Fluence dose, Dynalog files, RMS value

Introduction

The intensity modulated radiotherapy (IMRT) is widely used in clinical applications for treatment of malignant tumors with irregular shapes in specific sites. This treatment technique has superior dosimetric advantages over the 3DCRT. In the delivery of IMRT with dynamic MLC which is also known as sliding window technique, each leaf pair is unidirectional and moves continuously with independent speed while the beam is on. It can potentially benefit the patient in three ways. First, by improving dose conformity in the target, it can reduce the probability of recurrence. Second, by reducing irradiation of normal tissues, it can minimize the degree of morbidity associated with treatment. Third, by facilitating escalation of dose, it can improve local control. However, as the IMRT is a sophisticated treatment involving high conformity and high precision, it has specific requirements. The clinical implementation of IMRT requires special QA procedures specifically related to the machine and patient. Recent publications describe some new special procedures required to carry out the implementation of IMRT or provide guidance in introducing IMRT.

The purpose of this paper is to present our initial experience with the implementation of patient specific QA protocol at our center prior to the delivery of IMRT treatment with sliding window technique to the patients. After careful survey of the literature a patient specific pre-treatment QA protocol is formulated for our center. In order to validate our proposed protocol
two patient plans are done, one on patient’s CT images for the prostate PTV with six (6) fields and another on CT images for the Rando Neck phantom PTV with five (5) fields. In both the plans 6MV photon beams are used. The absolute and relative dose measurements are carried out to evaluate the accuracy of dose delivery for the pre-treatment verifications.

**Materials & Methods**

Varian Clinac 2300 CD linear accelerator with a 120 leaf millennium MLC is used to deliver the treatment plans. Eclipse 3D treatment planning system with Helios inverse planning software is used to create IMRT treatment and verification plans. OmniPro ImRT phantom with ImRT software (M/s Scanditronix Wellhofer) along with X-Omat V ready pack film and VIDAR-VXR 16 film scanner are used for film dosimetry. FC-65 and CC-01, ionisation chambers with Dose-1 Electrometer are used for absolute dosimetry. Varis-Vision networking systems along with dynalog file viewer software are used for the transfer, delivery, recording & verification of dynalog files of IMRT treatment plans.

Initially the two IMRT treatment plans of patients are finalized. Then verification plans are created on the CT images of IMRT phantom to evaluate the dosimetric validation of plans. Separate verification plans are created on IMRT phantom for each plan to verify point doses in absolute dosimetry. Three reference points, one at central axis (CAX) and two off axis points are created diagonally in coronal plane for the point dose measurements. Similarly separate verification plans are created for each plan to verify planar doses and fluence doses in relative dosimetry. All the verification plans are delivered on the IMRT phantom. The point doses are measured directly with the ionization chambers in absolute dosimetry and films are exposed for film dosimetry. The doses on the exposed films are measured with the help of film scanner and the OmniPro ImRT software. The absolute doses, planar and fluence doses calculated by the TPS for the verification plans are compared with the measured values.

The acceptance criterion for the absolute dose is considered adequate if the difference between the calculated and the measured dose is <3%. If the difference is 3% to 5%, the plan has to be verified; if it is >5%, the plan is to be rejected. The acceptance criterion in both the planar and fluence dose comparison for the relative dose is considered adequate if the difference between the calculated and the measured dose is <3%. If the difference is 3% to 5%, the plan has to be verified; if it is >5%, the plan is to be rejected. The dynalog files recorded during the treatment delivery of the two plans were analysed. This file records the planned versus actual position of each leaf in the MLC every 50 milliseconds during the treatment delivery of each field. The software generates data tables and plots the graphs of error histogram (leaf position deviations), error RMS (root-mean-square value of deviations) and beam hold-off Vs time (Shows No. of beam hold-off’s during treatment). In this case the acceptance criterion for each field is considered adequate if the error histogram shows >95% of the error counts have deviation misplacements<0.1 cm, the RMS value is <0.05cm and maximum number of beam hold-off’s per field is <2. All the observed results are compiled and compared with the standard values.

<table>
<thead>
<tr>
<th>Name of the verification plan</th>
<th>Absolute Dose difference (%) at various points</th>
<th>Relative dose difference (%)</th>
<th>Dynalog file analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Central axis</td>
<td>Off axis (left)</td>
<td>Off axis (right)</td>
</tr>
<tr>
<td>Ca-Prostate</td>
<td>0.19</td>
<td>1.6</td>
<td>1.75</td>
</tr>
<tr>
<td>Rando-Neck</td>
<td>0.83</td>
<td>2.91</td>
<td>3.62</td>
</tr>
</tbody>
</table>

Table 1. Comparison results of actual (TPS calculated) and measured (Linac delivered) verification plans.
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<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absolute dose for all treatment fields (Central axis point, Off axis points)</td>
</tr>
<tr>
<td>2</td>
<td>Relative dose for all treatment fields in axial plane (Planar dose)</td>
</tr>
<tr>
<td>3</td>
<td>Relative dose for all treatment fields in coronal plane (Fluence dose)</td>
</tr>
<tr>
<td>4</td>
<td>Analysis of dynalog files for each treatment field</td>
</tr>
<tr>
<td>5</td>
<td>Treatment position verification (Two Orthogonal Fields)</td>
</tr>
</tbody>
</table>

Table 2. Formulated Protocol for patient specific pre-treatment quality assurance.

Results

The results of absolute and relative dose comparison and dynalog files analysis are shown in Table 1. The central axis (CAX) and off axis point doses in Prostate plan showed 0.19%, 1.6% and 1.75% variations in absolute dosimetry. Similarly, the central axis, left side and right side off axis point doses in absolute dosimetry of Rando-Neck phantom plan showed 0.83%, 2.91% and 3.62% variations respectively. The planar and fluence doses in both the plans have shown less than 3% and in-between 3 to 4.5% variation respectively in film dosimetry. The dynalog file analysis has shown that the prostate plan has 99.34% and the Rando-neck plan has 98.35% of counts with less than 0.1 cm positional errors. The maximum RMS value of both the plans is 0.047. The formulated pre-treatment patient specific QA protocol is shown in Table 2.
Discussion

The reference points created for the absolute dose measurements in a coronal plane view of a verification plan is shown in fig.1. The central axis (CAX) point doses in both the plans and off axis point doses in Prostate plan showed less than 3% variation in absolute dosimetry. The right side off axis point dose in Rando-Neck phantom plan showed 3.62% variation in absolute dosimetry. This dose variation which is more than 3% can be attributed to the position of the point, which is in the dose gradient region and the smaller field sizes used.

The relative fluence dose comparison of Prostate plan along with the Gamma result is shown in fig.2. The relative planar dose comparison of Rando-Neck plan is done by two methods. In the first method all the fields are delivered on the phantom from various directions with the similar gantry angles used for the each field in the patient plan and, in the second method all the fields are delivered on the phantom from single direction anteriorly with zero degrees gantry angle. The plan comparison results of two methods are shown in fig.3 and 4 respectively. The fluence and planar doses in both the plans are compared with the isodose matching and profile matching methods. In both the plans it is noted that the comparison of data is matched with the correlation coefficient value greater than 0.99. The results are evaluated with the Gamma index method. The relative dose comparison revealed an average 97% of the data passes the criterion with dose variation less than 3% error. Only 3% of data is having dose variation in the range of 3-4.5%. Since the film dosimetry for the relative dose measurements is a cumbersome and time consuming method, nowadays in most of the busy centers, it is being replaced with the portal dose prediction software using the EPID.

The dynalog files verification results have shown that all the MLC movement parameters of the delivered treatment plans are well within the acceptable criterion. The maximum RMS value for the prostate plan is less with a value of 0.42 compared to that of 0.47 for Rando-neck plan. The less variations in the comparison of absolute and relative dose measurements in prostate plan than the Rando-Neck plan may be due to the effect of the field sizes used for the plans. In the Rando-Neck plan the field sizes are in the range of 5-6cm compared to the 8-9cm in prostate plan. During the delivery of all the fields in both the plans, not a single beam off interruption took place.

The results have shown that all the measurements are within the acceptable criterion as mentioned by Carlos D.V. and Pelayo Besa.[15] After the evaluation of the results of the two plans, we are following the formulated pre-treatment patient specific QA protocol as shown in table 2. Two orthogonal fields should be created as shown and they may be verified for the positional errors once in a week. The acceptance criterion in the comparison of setup errors of orthogonal fields with EPID films is less than 2mm.

Conclusion

All the patient specific QA tests have proved very useful and the observed minor deviations are within the acceptable limits. The QA tests presented in this paper will be adequate to deliver IMRT treatment with DMLC. We are following the proposed protocol of patient specific pre-treatment QA of IMRT at our center. The results are assuring the precision of IMRT treatment delivery at our centre.

References

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