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Dosimetric verification of pre-treatment intensity modulated radiation therapy in the commissioning process

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► ***Technical note***

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ABSTRACT

Background*:** Commissioning tests are recommended before implementing Intensity Modulated Radiation Therapy. This study evaluated five different plans of IMRT mocks for different modulation indices. ***Materials and Methods*:** IMRT tests were done in slab phantom for both 6MV and 15 MV photon energies using a 2D array ion chamber dosimeter. ***Results: The acceptance criteria were based on 3% /3mm. All tests passed the gamma criteria except for the prostate test with 15 MV photon beams and C shape test for both 6 MV and 15 MV energies. The Ratio passing points for Multi target test in 6 MV and 15 MV plans were 93.1% and 91.5%, respectively. The results of the prostate tests with 3%/3mm was 92.3% for 6MV and 91.2% for 15 MV in 4%/4 mm tolerance limit. For Head and Neck test with the same gamma criteria, the percentages of the points were 93.2 and 94 for 6 MV and 15 MV plans, respectively. For C shape tests, the used gamma criteria were 4%/ 4 mm. The ratio passing points were 94.9% and 94.3% for 6MV and 15MV plans, respectively. However, C shape hard test could not pass the gamma criteria of 4%/ 4mm for 6MV. ***Conclusion:*** results showed that by increasing the complexity of the IMRT plan, the verification test must be done in a more strict-manner, because a small change in dose delivery can cause a large discrepancy between planned and real dosimetry and may produce hot spots in organs or a cold spot in the target volume.

Keywords: *Pre- treatment IMRT, 2D array, IMRT mock, Gamma evaluation.*

INTRODUCTION

The use of Intensity Modulated Radiation therapy (IMRT) technique is growing in radiotherapy centers in Iran. Studies have shown the preference of IMRT for treatment of patients suffering from cancer due to its selective dose map for organ saving and dose escalation in order to produce a better tumor control with lower normal tissues complications (1-4).

IMRT conforms dose to the target volume but attempts to minimize the dose at nearby normal tissues assisting a complex modulation of the beam intensity. The application of this technology passes its learning curve in Iran, and because of the inherent complexity of IMRT from the points of physical and clinical matters, it is strongly recommended that radiotherapy clinics should have a precise and accurate commissioning program for their planning and delivery systems, based on the approved protocols for IMRT quality assurance (1-4). In this study, a set of commissioning tests were run based on task group-119 report (TG119) (5), report before clinical implementation of IMRT to warrant that all the planning and delivery systems work properly within an acceptable level. The tolerance level may be affected by different parameters such as differences in quality assurance (QA) phantoms and treatment planning systems (6). In this work, three different tolerance gamma indices were defined to find out the optimum tolerance level for treatment planning.

MATERIALS AND METHODS

Five different IMRT tests from the AAPM TG119 report were used in the Perspex slab phantom and the dose distribution of individual beams were measured and analyzed on a 2D array dosimeter through gamma factor evaluation. Using the maximum dose gamma value, three different gamma criteria (3%/3mm, 4%/4mm, 5%-5mm) were used to find out the best tolerance for different plans based on the existing facilities.

The Siemens primus linear accelerator (linac) (Siemens Co. from Germany) which is equipped by an add-on the multi leaf collimator (MLC) (from LINATECH support company) was used to deliver the IMRT dose. All tests were designed for both 6 and 15 MV photon beams in the step and shoot mode for the IMRT technique.

The Linatech treatment planning system (TiGRT version 1.0.8.545 from Linatech support Co.) was used for planning in order to deliver the modulated beams. The dose calculation algorithm of this TPS is the superposition convolution method.

Slab phantom (30x30x1.5 cm^3) with mean density of 1.18 g/cm^3 was used for simulation of different IMRT plans. To measure the dose distribution for each field at the isocenter plane, we used a PTW 2D-array with 729 ion chambers (PTW, Freiburg, Germany). The PTW Verisoft software version 5.1 (PTW Co. Freiburg, Germany) was also used to compare the IMRT dose map measurements on the 2D array against planning calculation. This software supports multiple dosimetric tasks including gamma index; calculation and evaluation based on the calculations of the dose difference (DD) and distance to agreement (DTA) parameters of dose distribution that is an accepted method to verify and report the accuracy of dose delivery within the specific dosimetric tolerance criteria. This software is dedicated for analyze the discrepancies between measured and calculated dose distributions. Three different tests were planned including; multi targets in which according to TG119 (5), three different targets are defined (figure 1a). Seven irradiation fields were defined along with different doses based on the dose constraints for each target (table 1). These tests were run for both photons of 6MV and 15MV for the step and shoot IMRT mode. In the mock prostate test; prostate gland and seminal vesicles were contoured as clinical target volume (CTV) while the bladder and rectum were contoured as normal tissue (figure 1). Seven beams at 50 degree intervals were planned for irradiation. The dose constraints for the organ at risks (OARs) and planning target volume (PTV) are shown in table 1.

In the head & neck mock; the head and neck PTV, Parotid glands and spinal cord are contoured on the slab phantom according to TG-119 (figure 1) (5). Nine fields with intervals of 40 degrees were planned to irradiate the target area. The dose constraints of the target and OARs are shown in table 1. For C shape test; the target surrounds a central normal structure as described in TG119 (figure 1). Nine radiation beams are defined with an interval of 40 degrees from the vertical angle. For these tests, one soft and one slightly hard to achieve dose constraints were considered. Table 1 also shows the lists of dose constraints.

Prior to measuring dose and dose distribution, a slab phantom consisting of a 2D array dosimeter at a depth of 5 cm was scanned for CT simulation and planning.

To measure dose distribution, a verification plan with different fields was exported on the phantom images for each field separately. The aim of this individual beam dosimetry is to avoid errors of the gravitational effect at different gantry angles. In addition, separated beams technique may show errors which might be masked by other beams in the combined beams technique [7]. The 2D array dosimeter was positioned at the isocenter depth. By applying gamma evaluation index, the measured fluence map was compared with the TPS calculated fluence map. Results were obtained by using a maximum dose gamma index.

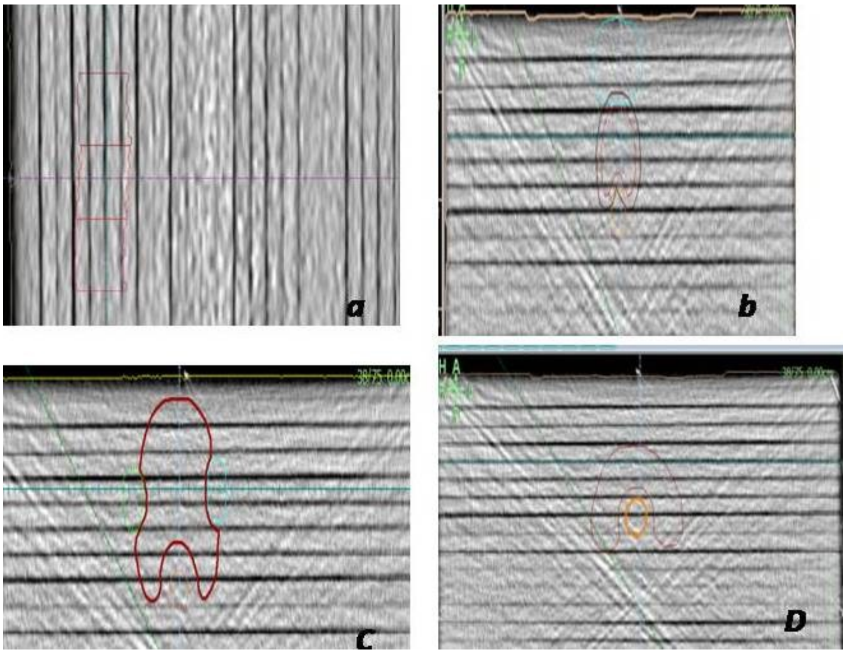

Figure 1. All Contours of the Mock tests in water equivalent slab phantom. **1-a** - Three different targets, (central target, superior and inferior target were contoured in Multi target test. **1-b-** CTV and PTV bladder and rectum as normal structure were contoured in mock prostate test. **1-c-** PTV, parotid glands and cord contoured in mock head and neck test. **1-d-** curved PTV and cord were contoured on cshape test.

Table1. Dose constraints for five different Mock IMRT tests.

Multi Target test		Mock prostate test.		H&N test		C-shape (soft & hard) test		
Targets	Dose constraints	Target/ OARs	Dose constraints	Target/OARs	Dose constraints	Target/ OARs	Dose constraints (soft)	Dose constraints (hard)
Central target	D_{99} > 50 Gy D_{10} < 53Gy	PTV	D_{95} > 75.60Gy D_5 < 83 Gy	$PTV_{H\&N}$	D_{99} > 46.50Gy D_{90} < 50 Gy D_{20} <55 Gy	PTV	D_{95} > 50Gy D_{10} < 55Gy	D_{95} > 50Gy D_{10} < 55 Gy
Superior target	D_{99} >25 Gy D_{10} <35Gy	Rectum	D_{30} >70 Gy D_{10} <75 Gy	Parotid glands	D_{50} <20Gy	Normal structure	D_{10} <25Gy	D_{10} <10 Gy
Inferior target	D_{99} >12.5 Gy D_{10}< 25 Gy	Bladder	D_{30} >70Gy D_{10}< 75 Gy	Cord	D_{max}<40Gy			

Table 2. The mean percentage of the points that passed different Gamma criteria's for each Mock tests for both 6 MV and 15 MV plans are shown.

DTA (mm)/DD(%)	Multi target	Mock prostate	Mock H&N	C shape (soft)	C shape (hard)
3m /3 % (6MV)	93.1±4.2	92.3±2	93.2±3.6	-------	--------
4 m / 4 %(6MV)	96.8±2.4	96.4±2.5	96.5±2.7	94.9±3.4	89±5.8
5 m / 5 % (6MV)	98.9±2.5	98.9±2	98.9±1.8	97.7±3	92.6±4.4
3m /3 % (15MV)	91.5±3.4	--------	94±2.9	----------	92.1±5.9
4mm/4 (15MV)	94±3.6	91.2±3	96.7±2.3	94.3±6	95.6± 4.9
5mm/5%(15MV)	95.8±5	95.3±2.4	98.6±1.3	97.7±3.5	98.7±2.5

RESULTS

All measurements were compared to the appropriate planned using Verisoft dedicated software based on gamma index criteria. Test points which passed the different criteria are shown in Tables.

The results showed that as the modulation index of the IMRT plan increased, the gamma value per field verification also increased. It has been shown that the percentage of points which passed the gamma criteria of 3%/3mm for multi target test in 6 MV and 15 MV plans were 93.1% and 91.5%, respectively. In mock prostate test with the same gamma criteria, the fraction of the points for 6MV plans were 92.3%; but for 15MV photon, prostate test passed the 4%/4mm gamma criteria by 91.2%. In addition, in the Mock Head and neck test with the same gamma criteria, the percentage of points that passed gamma were 93.2% and 94% for 6 MV and 15 MV plans, respectively. But in C-shaped tests, the gamma criteria of 4%/ 4mm was used and the percentage of the points passing this gamma criteria were 94.9% and 94.3% for 6 MV and 15 MV plans, respectively. The C-shaped hard test for 6 MV photon beam did not pass the gamma criteria of 4%/4mm. However, this test was passed with criteria of 3 % / 3mm for 15 MV with 92.1% value.

DISCUSSION

The commissioning tests were found to be useful for validating the accuracy of the planning system in different IMRT plans with different modulation indices. During the present study, we commissioned our systems based on TG119 recommendation. In this way, five different Mock tests were planned in the phantom . Comparing the planning results with the 2D array using three different tolerances, showed that most of the tests passed the gamma criteria of 3% /3mm except for the C-shaped (hard) test [8,9]. Researchers reported that the main sources of discrepancy between measured and calculated doses are positioning errors of MLC, inaccurate handling of small field dosimetry and also the number of MU/cGy [10-15]. In this work, C-shape test (soft and hard) had a large MU in comparison to the other tests which can be the cause of failing from the tolerance criteria of 3%/3mm in some 6MV photon tests. However, the 15MV photon C-shape test passed the gamma criteria of 3%/3mm because of lower MU for the 6MV photon beam. Other studies commissioned their systems using different dosimetry tools and methods and the different dosimetry tools may change criteria index [10, 16]. There is also a different appropriate tolerance of dose distribution for individual and combined fields due to gravity effect which can affect both the gantry rotation and the leaf motion [7]. Catharine *et al.* [7] suggested a gamma criteria of 3%-3mm for dose distribution for each field in head and neck plans, van Zitjveld [17], also suggested 3%/3 mm for individual head and neck field measured with an electronic portal device. Budgell *et al.* [8] suggested that 3%/3 mm was feasible for individual verification of prostate IMRT. Varatharaj *et al.* [9] used gamma criteria of 3% 3mm for brain as well as head & neck studies using film and 2D array per- patient dose verification. Also, Chung *et al.* [10] used gamma criteria of 3% / 3mm per-patient dose verification of 206 patients for different cases of prostate, abdomen, brain as well as head and neck studies. Their results showed that in head and neck cases, 3%- 3mm criteria was not passed as the modulation index of plans increased. Based on other studies and the present study, highly modulated plans seemed to be more sensitive to the accuracy of the tests. Therefore, different verification tests such as 3D dose verification must be conducted for them.

CONCLUSION

Mock- IMRT tests showed that the acceptance criteria of 3%/3mm is a proper tolerance level in mildly-modulated plans in our center and for highly modulated plans which do not pass the gamma criteria of 3%/3mm, different verification tests such as 3D dose verification of superimposed beams must be done to verify the accuracy of dose delivery.

Therefore, it is strongly suggested to do more verification tests in highly modulated plans in routine IMRT. In cases whose verification tests are out of action level (5%-5mm), changing the plans and constraint must be done to reach in tolerance level.

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