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Full Length Research Paper

Patient-specific quality assurance for the treatment of intensity modality radiation therapy of nasopharyngeal carcinoma

H. I. Al-Mohammed* and F. H. Mahyoub

Department of Biomedical Physics, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia.

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Nasopharyngeal carcinoma is the most common malignant tumor of the nasopharynx. The aim of this study was to assess and evaluate the significant of performing patient specific quality assurance (QA) for patients diagnosed with nasopharyngeal carcinoma treated with intensity modulated radiation therapy (IMRT). Ten pretreatment IMRT plans were selected for this study. The ten selected plans were treated with the split-field technique for intensity modulated radiation therapy planning using 10 MV beams with a prescribed dose total of 7000 cGy in 35 fractions. As a quality assurance protocol the two-dimensional ionization-chamber array was used. The study results showed agreement between the measured dose and the preplanned dose using the treatment planning system. All of the plans passed >95% gamma with the pixels within 4% distance to agreement (4 mm) for IMRT patient-specific QA. We concluded that IMRT has the ability to deliver a highly conformal dose distribution to the planned target volume while sparing the organs at risk. In addition, our results showed a very good agreement between the measured dose and the calculated dose which preceded it.

Key words: Radiation therapy, intensity modulated radiation therapy verification plan, gamma index, nasopharyngeal carcinoma.

INTRODUCTION

Radiation therapy is the primary treatment for non-metastatic nasopharyngeal carcinoma (NPC), although for stage III and IV carcinomas the treatment will include chemotherapy (Caponigro et al., 2010). With the new techniques developed in radiation therapy such as intensity modulated radiation therapy (IMRT) and image-guided radiotherapy (IGRT), the outcome of NPC treatments has improved and local control has been enhanced (Caponigro et al., 2010; Luo et al., 2010). IMRT is a highly conformal type of three-dimensional treatment (3-DCRT). It has the opportunity to deliver a higher dose to the tumor site, and reduces the risk of normal tissue toxicity or organ at risk (OAR), which then enhance patient survival rate and quality of life (Han et al., 2008). Treatment with IMRT fields has the ability to define the beam shape according to the tumor shape. The technique is based on delivering complex movements of a multileaf collimator (MLC) which consists of many small and irregular multileaf collimator fields or segments (Abate et al., 2009). The radiation dose during the treatment may be delivered either by the dynamic MLC (dMLC) method or multiple static field (MSF) or segmented MLC (sMLC) method (Williams, 2003). IMRT dose distributions are characterized by complex 3-dimensional (3-D) dose gradients and a time-dependent fluence delivery (Han et al., 2008), which means the pretreatment plan verification is compulsory. These treatments require a strict quality assurance program in order to assure the precise delivery of the prescribed dose and verification of an accurate dose (Soffietti et al., 2008). As a consequence of the complexity of the IMRT technique, additional dose checking methods are required to confirm the dose delivered to a patient treated with IMRT (Chen et al., 2002). The pretreatment IMRT verification criteria is based on two analyses: the analysis

*Corresponding author. E-mail: hmohamed@kfshrc.edu.sa. Tel: (+966-1) 464-7272, Ext: 35052. Fax: (+966-1) 442-4777.

Table 1. Patient characteristics.

Patient's No.	Gender	Patient's age	Stage
1	Male	43	T3N2M0
2	Female	55	T2N3M0
3	Male	67	T4N0M0
4	Male	63	T3N2M0
5	Female	73	T2N0M0
6	Female	56	T2N3M0
7	Male	47	T2N0M0
8	Female	64	T4N1M0
9	Male	49	T4N2M0
10	Male	59	T2N2M0

of a limited number of points in low-dose gradient areas, and the measurement of distances between isodose lines in high-dose gradient areas (Kapulsky et al., 2004). The quality assurance (QA) of IMRT plans includes several steps which then lead to the quality assurance for the whole treatment. These steps include a QA check of the multileaf collimator, the measurements of individual patient fluence maps, the calibration of the tools used, and the reproducibility of patient positioning (Oldham et al., 2006). The planned dose fluence is compared with deliverable dose fluence usually by using two-dimensional array with ionization chambers or electronic portal imaging devices (EPID) (Li et al., 2010). The purpose of this study was to evaluate our patient-specific QA for patients diagnosed with nasopharyngeal carcinoma and treated with IMRT. In this study we used a two-dimensional array with 729 ionization chambers, which is a portal dose device for IMRT plan verification.

MATERIALS AND METHODS

Patients characterization

Ten pretreatment IMRT plans were randomly selected for patients pathologically diagnosed with nasopharyngeal carcinoma without distant metastatic disease. Table 1 shows the patient characteristics. The total treatment prescribed dose to the gross tumor volume (GTV) and the planned target volume including the boost was 70 Gy in 35 fractions. The IMRT pretreatment plans for the ten plans consisted of 7 to 14 beams using 10 MV beams with total dose of 7000 cGy and the dose per fraction of 2.0 Gy.

IMRT QA procedures

Our IMRT pretreatment dose verification method consisted of the following two independent measurements: (1) point dose measurements at the isocenter using a two-dimensional detector matrix with 729 ionization chambers (2D-ARRAY) (PTW, Freiburg, Germany) and (2) using RadCalc (RadCalc, Lifeline Software, Inc., Tyler, TX) to check independent monitor units (MUs) for each beam. RadCalc calculation of depth was not evaluated in this study.

For the ten selected pretreatments plans, verification IMRT plans were created using Varian Eclipse external beam planning (8.1.18, Varian Medical Systems Inc., Palo Alto, CA). All IMRT verification plans have the same dosimetry parameters as the original plans. The dose was calculated in the system using 3-D dose distribution for each plan's field. Then, plans were exported to the treatment unit through ARIA Oncology (Varian Medical Systems Inc., Palo Alto, CA), an oncology-specific electronic medical record (EMR) connected through the network with all systems. This software manages clinical activities such as radiation treatment and patient data.

The two-dimensional array specifications

The two-dimensional array used in this investigation is 2D-ARRAY equipped with 729 vented plane parallel ion-chambers. The distance between chamber centers is 10 mm. These ionization chambers are uniformly arranged in a 27 × 27 matrix with an active area of 27 × 27 cm^2 and dimensional area of 22 x 300 x 420 mm, with interface area of 80 x 250 x 300 mm. The 2D-ARRAY chamber is calibrated using a setup of 10 × 10 cm field size, 100 MU, 10 MV beams at a depth of 10 cm and a dose rate of 300 cGy/MU.

Methods and setup

For the verification plans, the 2-DARRAY setup consisted of three solid water slabs of poly methyl methacrylate (PMMA) with deferent thickness (3, 4 and 1 cm). A 3 cm thickness slab was used under the 2D-ARRAY chamber as a backscatter phantom, and the other two slabs of 5 cm are used above the array as buildup to simulate a depth of 10 cm in the patient. The chamber center was aligned with the isocenter of calculations and plans. The 2D planar dose distribution was calculated at a 10 cm depth in the phantom using a 1 mm pixel dose grid resolution, and the point dose was calculated at the isocenter and reference point 5 mm behind the surface. The individual fields are radiated in gantry and collimator positions of 0° angle on the array and source-to-surface distance (SSD) of 94.5 cm, using a dynamic multileaf collimation on a Varian linear accelerator Clinac 21EX equipped with a 120-leaf Millennium (MLC) (Varian Medical Systems Inc., Palo Alto, CA). The MLC system has 60 pairs of leaves in each bank and the MLC leaf width projected at isocenter is 1 cm. The leaf ends are rounded. The 2D-ARRAY chamber is connecting to a laptop computer outside the treatment room which runs software from PTW. The software which recorded the measurements with the 2D-ARRAY is MatrixScan (PTW-Verisoft3.1). Prior to the measurement the temperature, pressure

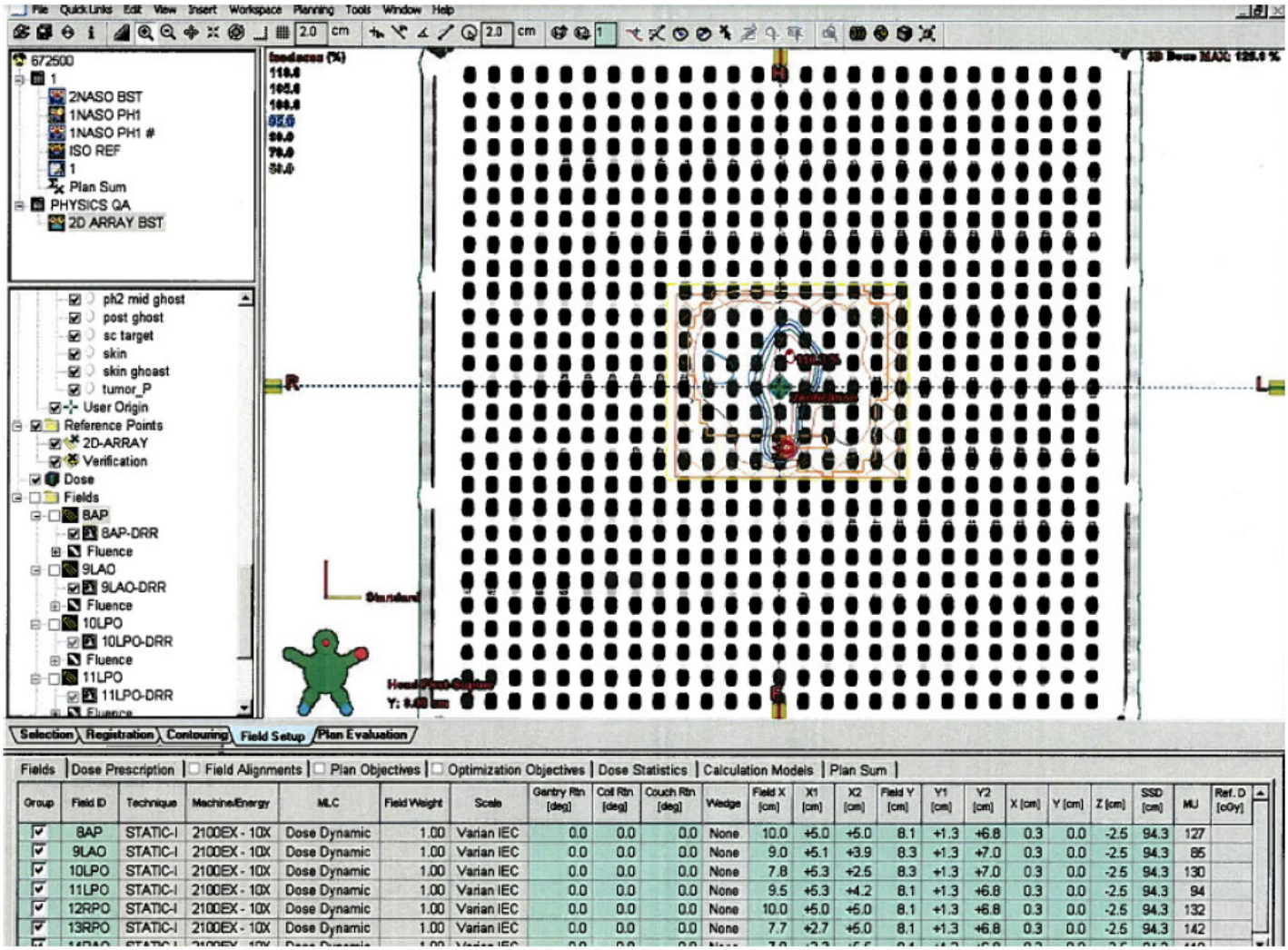

Figure 1. Showing the 2-DARRAY verification plan from the TPS, the total number of field, the energy, the field setup, the number of MUs and the isodose line.

and a correction factor for the machine is entered into the MatrixScan software. Each beam of the pretreatment plan is delivered to the 2D dose detector, thus the dose at some reference points can be calculated. Every field is irradiated in each plane one after another on the 2D-ARRAY without interruptions or entering the treatment room, and the combined dose measured reflects the contribution from all beams for every plane.

The measured dose distributions were then compared to those calculated by Eclipse TPS using PTW VeriSoft analysis software. A print out of a verification plan from TPS for the boost plan shows the number of fields, number of MUs, fraction dose; the actual measured dose is handwritten. The verification software is based on the gamma index criterion, which in this study was set as the dose difference (DD) in pixels within 4% and distance to agreement (DTA) of 4 mm, as well as gamma values (γ) (dose 4%, distance 4 mm).

Statistical analysis

Data from each sample were run in duplicate and expressed as means ± SD (cGy, n = 10 patients). The results were compared using one-way ANOVA analysis followed by Tukey's test for multiple comparisons. Means were considered significant if $P<0.05$. Means were considered significant if $P < 0.05$. Statistical analysis was performed by means of GraphPad Prism™ package for personal computers (GraphPad Software, Inc., San Diego, USA) and figures were drawn by means of GraFit™ package for personal computers (Erithacus Software Limited, Surrey, UK).

RESULTS

In our study we evaluated our QA system of IMRT plans that used to treat patients with nasopharyngeal carcinoma. Presently, we performed routine QA measurements for each IMRT patient either immediately prior to the treatment or shortly after the first treatment. Figure 1 shows a representative 2D-ARRAY verification plan, showing the total number of fields, the energy, the field setup, the number of MUs, and the isodose line. Figure 2 shows the print out of a representative

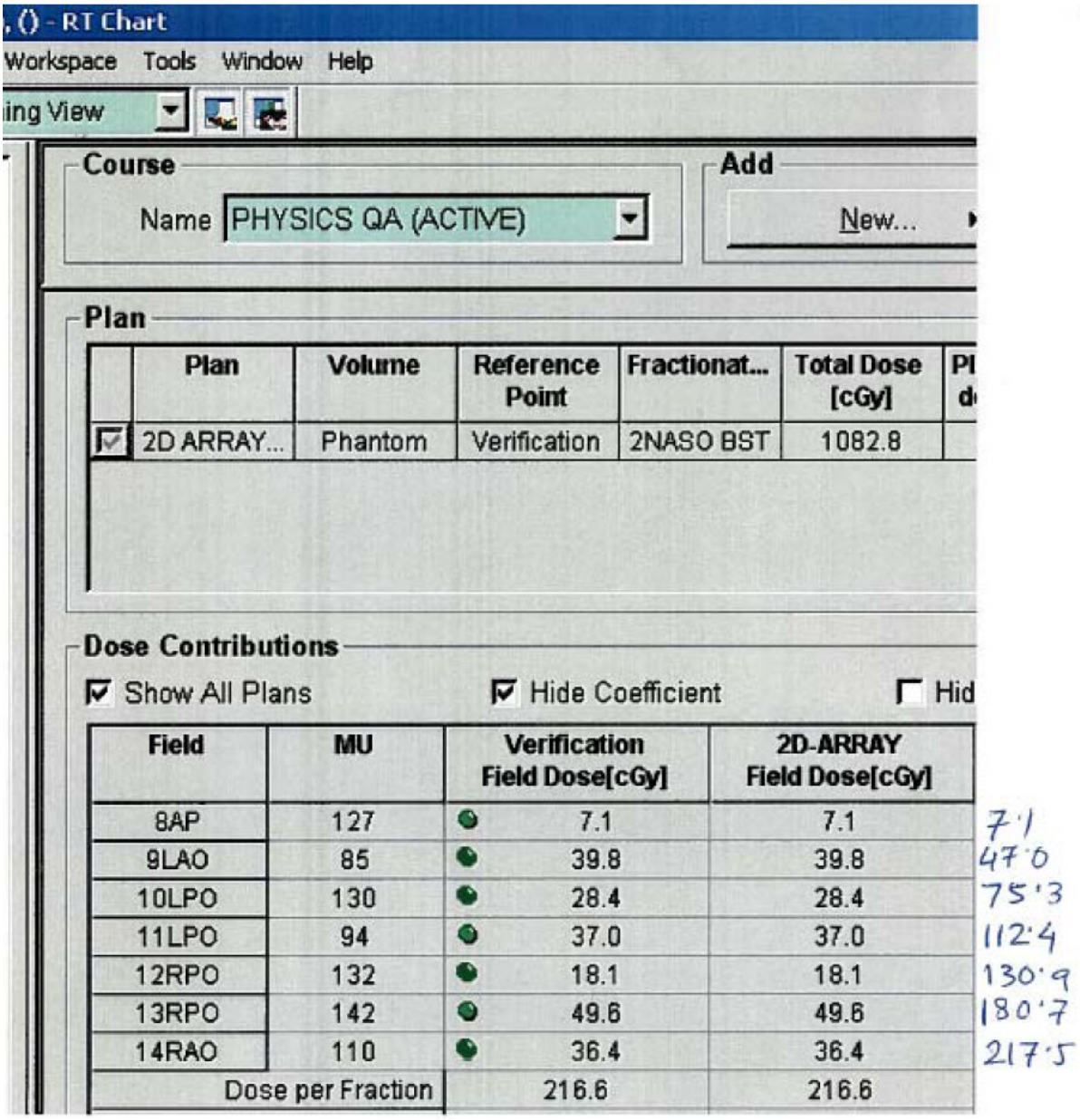

Figure 2. Showing one example of compression dose between the dose planned for each field and the measured dose by 2D-ARRAY and the total fraction dose for each.

verification plan from TPS for the boost plan phase 2 of a nasopharyngeal carcinoma treatment, showing the number of fields, number of MUs, fraction dose, and the actual measured dose (handwritten). Figure 3 shows a representative comparison between the planned dose and the measure dose using gamma index.

Table 2 shows the total number of IMRT fields for the ten selected pretreatment plans evaluated. It shows the prescribed dose, the fraction planned dose from TPS, the measured dose from the 2D-ARRAY, the percentage dose differences and the percentage of pixels passing gamma criterion. The result shows an average discrepancy of less than 0.1% (SD < 0.004%) for ionization chamber measurements in comparison to TPS. The average dose difference between planned and measured dose was 0.22% with standard deviation of 0.87%. Our passing criteria for IMRT plans was based on the percent of pixels passing gamma > 95% within the passing criteria of dose difference (DD) (pixels within 4% distance to agreement (DTA) and 4 mm DTA). Thus, all of our ten selected pretreatment plans, with an average 99.3% pixels with SD 0.004%, passed the gamma analysis test. The result shows an agreement between the measurement by the 2D-ARRAY and the calculation

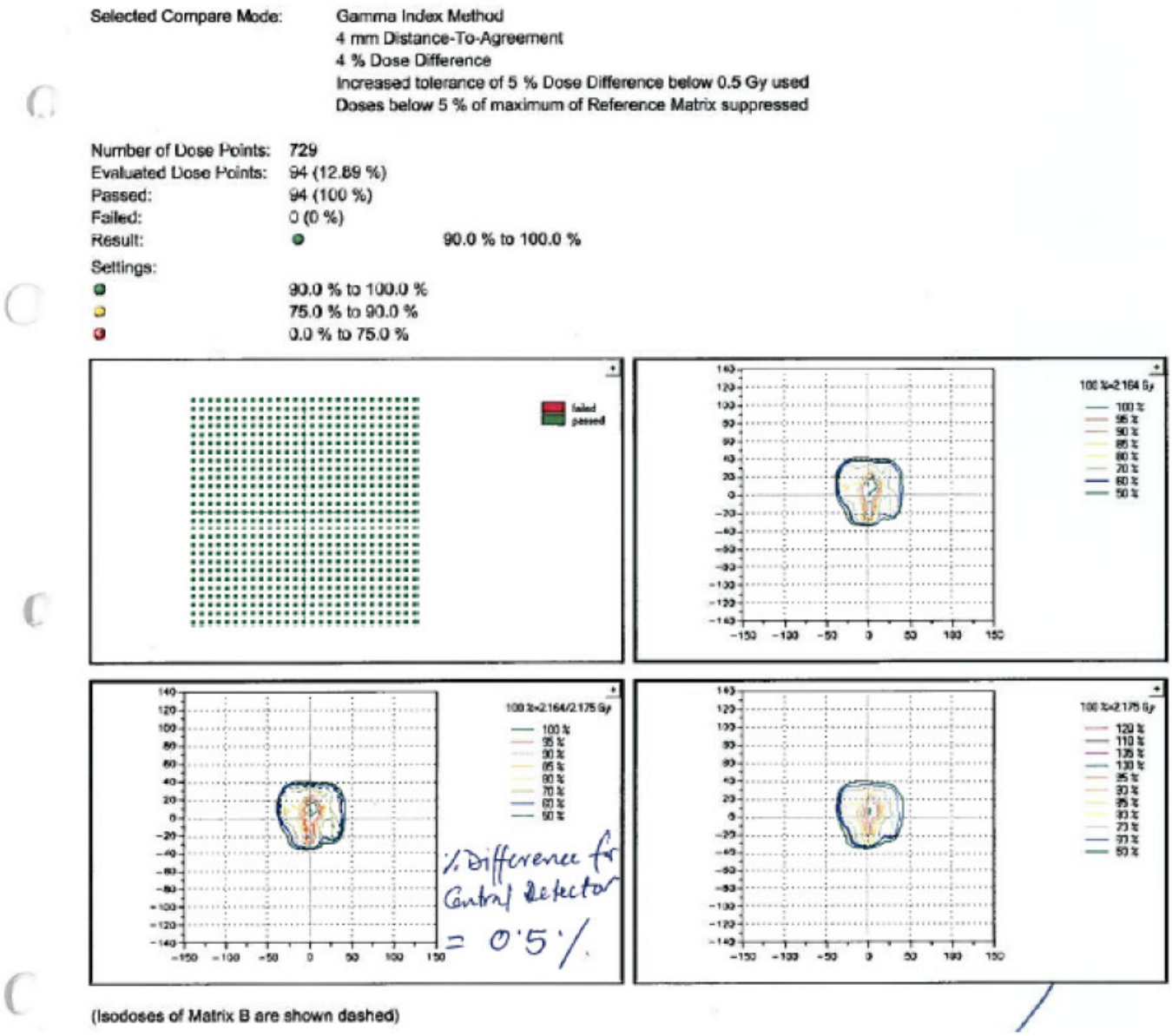

Figure 3. Showing result of measured dose in compression with the planned dose from the verification software which is base on the gamma index criterion.

of composite plan absolute dose. Every point measured in these plans agreed to within a ± 5% acceptability criteria of the dose calculated by the planning system and the chamber measured dose.

DISCUSSION

External beam radiation therapy (EBRT) is the main modality in treating cancer, alone or in combination with other modalities such as surgery or chemotherapy (Al-Mohammed, 2010, 2011). IMRT) gives a higher dosimetric conformity for normal tissue sparing in patients with nasopharyngeal carcinoma and at the same time, it reduces the toxicity to many normal tissues or organs at risk (Chao et al., 2001). An IMRT treatment plan is a complex radiotherapy treatment plan that requires a comprehensive QA for field-by-field, in addition to complex analysis methods (Depuydt et al., 2002; Poppe et al., 2006). The need for the sophisticated treatment plans and measurements increases if we are treating a tumor in the head and neck area such as a nasopharyngeal tumor where is the planned target volume is surrounding by many organs at risk (OAR) such as parotid glands and spinal cord (Chao et al., 2001). In our study we evaluated our QA system of IMRT

Table 2. This table illustrates the total number of IMRT fields that been measured, the fraction dose for planned and measured, RadCalc Calculations, the % dose different between TPS and VeriSoft software measured dose and % of pixels passing gamma criterion

Patient's IMRT fields numbers	Total dose cGy	Fraction planned dose cGy	Fraction planned dose from TPS cGy	Radcalc dose cGy	% dose difference between RadCal and TPS	2-DARRAY Measured dose cGy	% dose difference between TPS and VeriSoft software measured dose	% pixels passing gamma criterion
7	7000/35	200	200.5	202.9	1.2	199.6	-0.4	99.6
14	7000/35	200	189.8	194.8	-3.0	191	0.6	99.4
7	7000/35	200	208	210.2	1.0	209.3	0.6	99.4
12	7000/35	200	217.6	221.7	1.2	217.5	-.04	99.6
7	6600/33	200	211	214.3	1.5	212.3	0.6	99.4
12	7000/35	200	203	209.2	3.1	204	0.5	99.5
7	7000/35	200	197.8	200.8	1.7	199.2	0.7	99.3
14	7000/35	200	217	221.1	0.46	218.4	0.6	99.4
7	7000/35	200	212	209	-1.4	210.9	- 0.5	99.5
14	7000/35	200	192.8	195.3	1.2	193.1	0.15	99.8
Total= 101		Average dose =200	Average dose = 204.95	Average dose = 207.93	Average dose =0.70	Average dose =205.53	Mean =0.00280. SD =004%	Mean = 99.5% SD =0.0014 %

plans used to treat patients with nasopharyngeal carcinoma. The ten selected pretreatment IMRT plans were evaluated using 2D-ARARY chambers. For each plan an individual analysis was run with the same criteria. All the ten selected pretreatment plans were accepted for clinical use and all of the plans successfully passed the gamma analysis criterion with more than 95% of the pixels in the defined field size.

Conclusion

This study evaluated the IMRT QA used in our department for patient specifications using a 2D ion-chamber measurement. The result of our study showed that the gamma index analysis supplied an agreement of more than 95% of the dose. Dose-point was Pγ >95% within acceptance criteria, in terms of dose difference and distance-agreement equal to 4% and 4 mm, respectively. The result shows a very good agreement between measured dose and calculated dose of the TPS, proving that our treatment planning using patient-specific IMRT QA is sufficient practice for IMRT treatment.

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