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Pretreatment Dose Verification for Squamous Cell Carcinoma of the Tongue

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Abstract

The aim of this study is to assess and to evaluate the significant of performing patient's specification quality assurance (QA) for patients diagnosed with squamous cell carcinoma of the tongue (SCC) whom treated with intensity modulated radiation therapy (IMRT). The study was done in ten pre- treatment's plans that been prepared for patients. All the ten selected plans are going to be treated with split-field (SF) technique for intensity modulated radiation therapy (IMRT) planning using 10 MV beams and a prescribed dose between 66Gy and 74 Gy. For quality assurance protocol we are using the two-dimensional ionization-chamber array. The study showed that an agreement between the measured dose and the pre-planned dose using the treatment planning system. All the plans passed >95% Gamma with the pixels that within 5% distance to agreement of 5 mm for IMRT patient-specific quality assurance (QA). It concludes that intensity modulated radiation therapy (IMRT) has the ability to deliver a highly conformal dose distribution to the planning target volume (PTV) while sparing the organs at risk in the surrounding area. The result showed a very good agreement between measurements dose and calculations dose which proven that the IMRT patient-specific quality assurance (QA) that we used is accurate and sophisticated to be used.

Keywords: Radiation therapy; External beam radiation therapy; IMRT verification plan; Gamma index; Intensity modulated radiation therapy; Treatment planning system; Squamous cell carcinoma

Introduction

The most common site of primary squamous cell carcinoma (SCC) in the oral cavity is the tongue. It is considered as the sixth most common cancer of oral cavity [1]. The incidence of oral cancer SCCs would increase as the age increase, with a median age of 61 years at the time of diagnosis [2]. The prognosis of oral cancer SCCs pathologies depends on many factors that include the sizes of the primary tumor, the site of the tumors, lymph node involvement, metastasis of the tumors to other structures and organs and finally to the differentiation degree of the tumors [3]. The prognosis of oral cancer SCCs remains low with an average of five years survival rate below 50%, producing high rates of mortality and morbidity [4]. The treatments of squamous cell carcinoma (SCCs) in the oral cavity are including combinations of surgery, radiation therapy and chemotherapy surgery [5].

Intensity-modulated radiotherapy (IMRT) is a highly conformal type of three-dimensional treatment (3-DCRT) planning radiation therapy. IMRT planning has the opportunity to deliver a higher dose to the tumor site where as it reduces the risk of normal tissue toxicity or organ at risk (OAR) , which then enhance patient survival rate and the quality of life [6]. The treatment with IMRT fields has the ability to define the beam shape according to the tumor shape. Thus these treatment' fields are delivering via complex movement of multileaf collimators (MLC). It consists of many small and irregular multileaf collimators fields or segments [7]. The radiation dose during the treatment could be delivered either by dynamic MLC (dMLC) method or multiple static field (MSF) or segmented MLC (SMLC) method [8], however, the explanations of each technique is out of the scope of this study. IMRT dose distributions have the characterization of complex 3-dimensional (3-D) dose gradients and a time-dependent fluence delivery [9], which made the pre-treatment plan verification a compulsory and a routinely check. The treatment required an enormously quality assurance in order to assure that the precise delivery of the prescribed dose and the precise verification of the accurate dose [10]. As a consequence of the complexity of the IMRT technique, additional dose checking methods are required to conform of the dose of all patients treated with IMRT [11]. The pre-treatment IMRT verification criteria is based on two analysis which are; the analysis of a limited number of points in low-dose gradient areas, and secondly is the measurement of distances between isodose lines in high-dose gradient areas [12]. The inspection method for IMRT or the quality assurance (QA) of IMRT plans encloses several steps which then lead to the quality assurance for the whole treatment. These steps are including the multileaf collimators (MLC) QA, the measurements of individual patient fluence maps, the calibration of the tools used and finally the reproducibility of patient positioning [13]. The planned dose fluence is compared with fluence of the dose to be delivered by using two-dimensional array with ionization chambers or electronic portal imaging devices (EPID) [14].

The purpose of this paper is to evaluate the significant of performing patient's specification quality assurance (QA) for for patients who diagnosed with squamous cell carcinoma of the tongue and treated with intensity modulated radiation therapy (IMRT). In this study we used the two-dimensional array with 729 ionization chambers, which is a portal dose device for IMRT plan verification. The Ethics and Research Committee of the department approved this study.

Materials and Methods

Ten per-treatment IMRT plans are selected for patients pathologically diagnosed with primary poorly differentiated squamous cell carcinoma; aged mean was 55 years (range between 46 years to 63 years). Total treatment doses ranged between 66Gy and 74 Gy, which is including the first phase of treatment and the boost to the planning target volume (PTV). IMRT pretreatment dose verification method consists of two- independent measurements: the first one is the point dose measurement at the isocenter using two-dimensional detector matrix with 729 ionization chambers (PTW, Freiburg, Germany) and the second one is using RadCal ((RadCalc, Lifeline Software, Inc., Tyler, TX) to check independent MUs for each beam, however, the RadCalc calculation is out of the scope of this study. For all of the ten pre-treatments selected plans, verification IMRT plans were created using Varian Eclipse external beam treatment planning system (8.1.18, Varian Medical Systems Inc., Palo Alto, CA). All IMRT verification plans had the same dosimetricly parameters of the original plans (Figure 1 Showing the 2-DARRAY verification plan from the TPS, it shows the total number of field, the energy, the field setup and the number of MUs and the isodose line). Then the dose will be calculated in the system using 3-D dose distribution for each plan's field. Then after that the plan is exported to the treatment unit via ARIA Oncology system (Varian Medical Systems Inc., Palo Alto, CA), which is an oncology-specific electronic medical record (EMR). The ARIA system is connected through the network with all of the systems. It manages all the clinical activities such as radiation treatment and patient's data.

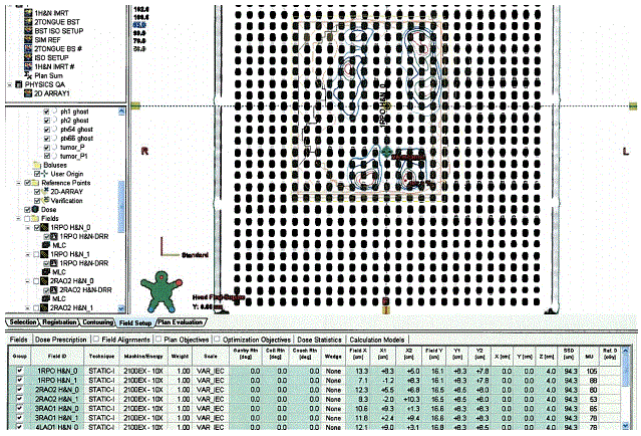

Figure 1: Showing the 2-DARRAY verification plan from the TPS, it shows the total number of fields, the energy, the field setup and the number of MUs and the isodose line.

The two-dimensional array used in this investigation is 2-DARRAY equipped with 729 vented plane parallel ion-chambers, the distance between chamber centers is 10 mm. These ionization chambers uniformly arranged in a 27 × 27 matrix with an active area of 27 × 27 cm2 and dimension area of 22 mm × 300 mm × 420 mm, interface: 80 mm × 250 mm × 300 mm. The 2-DARRAY chamber is calibrated using the setup of 10 cm × 10 cm field size, 100 monitor unit (MU), 10 MV beams at depth of 10 cm and a dose rate of 300 cGy/Mu. For the verification's plans, the 2-DARRAY setup consists of three solid water slabs of poly methyl meth acrylate (PMMA) with deferent thickness (3 cm, 4 cm and 1 cm). A slab with 3 cm thickness used under the 2-DARRAy chamber as a backscatter phantom, where are the other two slabs of the thickness of 5 cm are used above the array that are considered as buildup unit to simulate the depth of 10 cm in the patient. The chamber center was aligned with the isocenter of calculation and plan. The 2D planar dose distribution was calculated at 10-cm depth in the phantom using 1-mm-pixel dose grid resolution, and the point dose was calculated at the isocenter. The reference point is at 5 mm behind surface. Each individual field is radiated in gantry and collimator position of 0° on the array and source to surface distance (SSD) of 94.5 cm, using dynamic multileaf collimation on a Varian linear accelerator Clinac 21EX equipped with with120-leaf Millennium (Varian Medical Systems Inc., Palo Alto, CA). The MLC system has 60 pairs of leaves in each bank; the projection of MLC leaf width at isocentre is 1 cm. The leaf is rounded at the end. The 2-DARRAY chamber is connect to laptop outside the treatment room which runs a supported software that made by PTW. The software is MatrixScan (PTW-Verisoft3.1) which will record the measurements with the 2D-ARRAY. Prior to the treatment the temperature, pressure and a correction factor for the machine is entered into the MatrixScan software. Each beam of the pre-treatment plan is delivered to 2D dose detector, thus the dose at some reference points can be calculated. The measured dose distributions were then compared to those calculated with Eclipse TPS. The IMRT treatments plans for all of the ten patients consisted of 7 to 16 fields using 10 MV beams with total dose ranges between 66Gy to 74 Gy and the dose per fraction ranges between 2.0 Gy to 1.8 Gy. Every field is irradiated in each plan one after another on the 2D-ARRAY without interruptions or entering the treatment room. Then, the combined dose that measured is reflecting the contributions from all beams for each plan. All data is recorded in Verisoft, figure 2 is showing the print out of verification plan from TPS for phase one and phase 2 of carcinoma of the tongue, in addition, it shows the number of fields, numbers of MUs, fraction dose , and the actual measured dose which shows by handwritten. Then result data from the measurement by 2-DARRY compared with the planned dose using verification software that based on the gamma index criterion (Figure 3). Comparisons between measured and calculated dose distributions are reported as dose difference (DD) (pixels within 5%), distance to agreement (DTA) (5 mm), as well as gamma values (γ) (dose 5%, distance 5 mm).

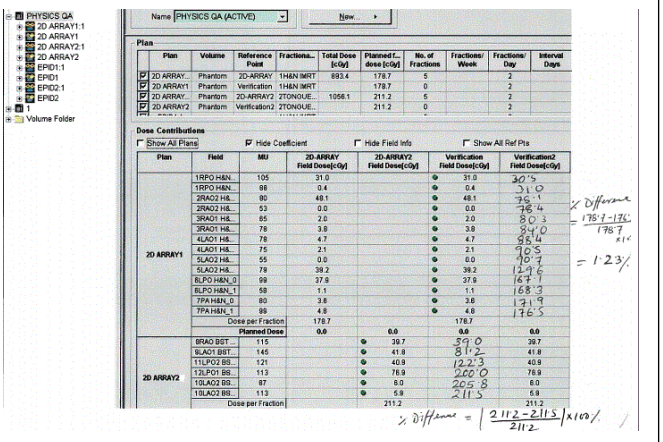

Figure 2: Showing the print out of verification plan from TPS for phase one and phase 2 of squamous cell carcinoma of the tongue, it shows the number of fields, numbers of MUs, fraction dose, and the actual measured dose which shows by handwritten.

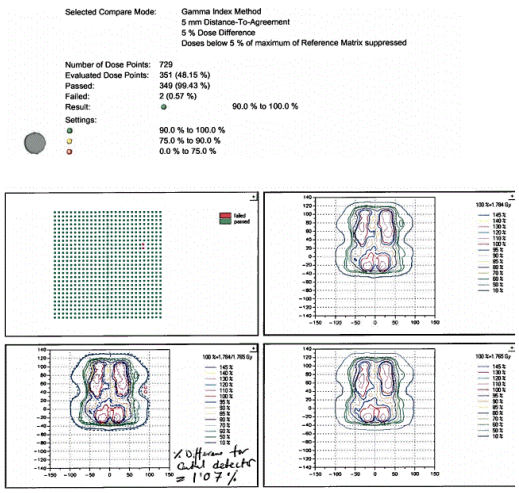

Figure 3: Showing the matrix of isodose compression between the planned dose in TPS and the measured dose by 2-DARRY ion chambers, where the matrix for measured dose is shown dashed. In this data 99.43% of the evaluated points passed.

Results and Discussion

In this study we evaluated the QA system of IMRT plans that used to treat patients with squamous cell carcinoma of the tongue. Presently, we perform routine QA measurements for each IMRT patient either immediately prior to the treatment or shortly after the first treatment. Table 1 shows the comparison of the dose measured and planned for each field of the selected plans. The average dose difference between planned and measured dose was 0.22% with standard deviation of 0.87%. Since the passing criteria for IMRT plans based on that the plan will be acceptable in case of the percent of pixels passing gamma >95% within the passing criteria of dose difference (DD) (pixels within 5% distance to agreement (DTA) (5 mm) 5 mm DTA, thus all of the ten selected pretreatment plans passed on an average 99.3% pixels with SD 0.004%, passed the gamma analysis test.

Table 1, shows the total number of IMRT fields for the ten selected pre-treatment plans that been measured. It shows the prescribed dose, the fraction planned dose from TPS, the measured dose from the 2-DARRAY, the percentage dose differences and the percentage of pixels passing gamma criterion. The result shows that average discrepancy of less than 0.1% (SD <0.004%) for ionization chamber measurements in comparison to the TPS.

Patient's fields numbers	Fraction Planned Dose cGy	Fraction planned dose from TPS	2-DARRAY Measured dose cGy	% dose difference between TPS and VeriSoft software measured dose	% of pixels passing gamma criterion
7	200	208	209.7	0.80%	99.20%
8	200	208	209.3	0.60%	99.40%
11	200	187	190	1.60%	98.40%
7	180	178.4	176.5	-1.06%	99.40%
8	200	189	187.8	-0.60%	99.20%
11	180	185	186.1	0.60%	99.50%
16	200	198	199.3	0.65%	99.50%
8	200	211.5	211.2	-0.14%	99.90%
14	180	177	178.2	0.70%	99.30%
13	180	178	176.3	-0.95%	99.50%
Total field number=103	Average Dose=192	Average Dose=190.56	Average Dose=192.44	SD=0.87%, Aver=0.22%	SD=0.004% Aver=99.3%

Table 1: Showing the total numbers of treatment fields for the ten pre-treatment IMRT plans. It shows the prescribed dose, the fraction planned dose from TPS, the measured dose from the 2-DARRAY, the % dose differences and the % of pixels passing gamma criterion.

External beam radiation therapy (EBRT) considered as the main modality of treating cancer either alone or in combination with other modalities such as surgery or chemotherapy [15,16]. Intensity-modulated radiation therapy (IMRT) gives higher dosimetric conformity for normal tissue sparing in patients with squamous cell carcinoma of the tongue [17]. IMRT treatment plan is complex radiotherapy treatment plan that is required a comprehensive QA for field-by-field, in addition to a complex analysis method [18]. The necessity for the sophisticated treatment plan and measurement increases if we are treating a tumor in the brain where the planning target volume (PTV) is surrounding by many organs at risk (OAR). In this study we evaluated the QA system of IMRT plans that used to treat patients with carcinoma of the tongue our department. The ten selected pre-treatment IMRT plans were evaluated using 2-DARARY chambers.

For each plan an individual analysis runs with the same criteria, Figure 3 is showing the compression between the planned dose from the treatment planning system TPS and the measuring dose using gamma index. For the first patient the fraction planned dose from the treatment planning system was 208 cGy according to the prescribed isodose lines, where the measured dose by the 2-DARRAY was 209.7cGy with percentage dose difference of 0.8% and percentage of pixels passing of gamma criterion is 99.2%.,where for the second patients with the prescribed dose of 208 cGy the measured dose was 209.3 cGy with % dose difference of 0.6% and percentage of pixels passing of gamma criterion is 99.4% The percentage dose difference for the third patient was 1.6%, where the fraction planned dose was 187 cGy and the measured dose was 190 cGy, the percentage of pixels passing gamma criterion is 98.4%. The fourth plans was a seven fields planned with 178.4 cGy planned freaction dose in treatment planning system where the measured dose is 176.5 cGy, the percentage dose difference between the treatment planning system and the measured dose decreased by 1.06% and the percentage of pixels passing gamma criterion is 98.4%.In the fifth plan with eight IMRT treatments fields, the fraction planned dose was 189 cGy where the fraction measured dose by 2-DARRAY ion chambers is 187.8, which gave a decreasing in a percentage dose difference of 0.6% and percentage of pixels by 99.2%. For the sixth pre-treatment plan with eleven IMRT fields, the fraction planned dose was 185 cGy, the 2-DARRAY measured dose was 186.1 cGy, the percentage dose difference was 0.6% and the percentage of pixels passing gamma criterion is 99.5%. The pre-treatment plan for the seventh one was 16 IMRT fields with fraction planned dose of 198 cGy and a measured dos of 199.3, which gave a percentage dose difference of 0.65% and percentage of pixels passing the criteria is 99.5%. For the eighth planned the fraction planned dose was 211.5 cGy where the measured dose was 211.2, which gave a decrease percentage dose difference of 0.14%, and passing criteria of 99.9%. For the ninth pre-treatment planned with fourteen IMRT treatment fields, the planned fraction dose was 177 cGy, where the measured dose was 178.2 cGy which gave a percentage difference of 0.7% and a percentage of passing criteria of 99.3%. Finally, for the last pre-treatment plan that has thirteen fields and fraction planned dose of 178. The 2-DARRAY measured dose for each fraction was 176.3, the percentage dose difference between the planned and the measured dose decrease by 0.95%, and the percentage of pixels passing gamma criterion was 99.5%.

The result showed an agreement between the measurement by the 2-DARRAY and the calculation of composite plan absolute dose. Every point measured in these plans agreed to within ±5% acceptability criteria, of the dose calculated by the planning system and the chamber measured dose. All the ten selected pre-treatment plans were acceptable for clinical use and all of the plans successfully passed the gamma analysis criterion with more than 95% pixels in defined field size.

Conclusion

This study evaluated the IMRT QA that we used in our department for patient's specification using acceptance 2D ion-chamber measurements for IMRT. The gamma index analysis supplied an agreement of more than 95% of the dose. Dose-point Pγ >95% within acceptance criteria, in terms of dose difference and distance-agreement equal to 5% and 5 mm, respectively. The result showed a very good agreement between measured dose and calculated dose of the TPS which proven that the treatment planning patient-specific IMRT QA that we are using is sufficient practice for IMRT treatment.

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Conflict of Interest

The author of this study certifies that this manuscript has not been published in whole or in part nor is it being considered for publication elsewhere. The authors indicate no disclosure of potential conflicts of interest.

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