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Commissioning and quality assurance of a commercial intensity modulated radiotherapy (IMRT) treatment planning system PrecisePLAN

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ABSTRACT

The objective of this paper is to present our experience in the commissioning and quality assurance (QA) of PrecisePLAN treatment planning system for intensity modulated radiotherapy (IMRT) using multileaf collimator (MLC), step and shoot technique. The data were obtained during the installation, acceptance test procedure, and commissioning of the unit. The dosimetric data were taken using CC13 pin-point ion chamber (Scanditronix Wellhofer). The beam profiles for various field sizes in the x, y, and diagonal directions were measured. The basic dosimetry parameters such as percentage depth dose (PDD), off-axis-ratio (OAR), output factor, and scatter factors needed for patient treatment were evaluated. Point dose measurement and fluence maps did the treatment dose verification. [Turk J Cancer 2007;37(1):22-26]

KEY WORDS:

Intensity-modulated radiotherapy, commissioning, quality assurance

INTRODUCTION

Intensity modulated radiotherapy (IMRT) can be delivered with two main modalities: segmental IMRT (step and shoot) and dynamic IMRT (sliding window). For the step and shoot modality, the multileaf collimator (MLC) shape remains constant while the beam is on and changes while the beam is off. For the sliding window, each leaf pair moves continuously, unidirectionally, and with independent speed while the beam is on (1-5).

The commissioning of the dose calculation algorithms of a treatment planning system is generally performed by entering the basic beam data into the system according to the methods and requirements described in the system user manual and by comparing the results of dose calculations with the entered data and with data that were measured specifically for this purpose.

The purpose of this paper is to present our experience with the commissioning and quality assurance (QA) of PrecisePLAN treatment planning system with multileaf collimator using step and shoot IMRT technique.

MATERIALS AND METHODS

The LINAC system

A new dedicated IMRT unit Elektas (precise) linear accelerator was used in this study. The upper-jaws of the linear accelerator were replaced with 40 leaf pairs called multileaf collimator along with back up diaphragms. The width of each leaf was 1cm.

The Blue PhantomTM Radiation Field Analyser was accurately positioned in the treatment room and left there for at least 2 hours in order to reach temperature stability. The measured data were evaluated with great care in order to construct a data set with great consistency.

PrecisePLAN treatment planning system

A 3D treatment planning system (TPS) for intensity modulated radiotherapy using a multileaf collimator has been made available by Elekta. Two approaches of computerized treatment planning for step and shoot IMRT are generally applied: the first method is an extension of conventional treatment planning and is referred to as forward planning. Its definition of the segment shapes is performed manually similar to conventional planning. However, more than one segment is used from each beam direction. Afterwards, the weights of the segments are optimized using a computer optimization algorithm to achieve the desired dose distribution (6). The second strategy, which we denote as inverse planning, usually starts with the optimization of fluence profiles from each beam direction by minimization of an objective function. Afterwards, sequencing transforms each optimized profile into a series of segments, which can be delivered with a multileaf collimator.

Dosimetry

The following basic dosimetric parameters were measured for the purpose of modeling the 6 MV photon beam for the treatment planning system used in this study.

Depth dose data

The depth dose data for open beams were measured for 3, 5, 6, 8, 10, 12, 15, 20, 25, 30, 40 (cm x cm) square field sizes, for depths from 0 to 22 cm. The depth dose data for 60° wedged fields for square field sizes of 3, 5, 6, 8, 10, 12, 15, 20, 25, and rectangular field 30 x 40 (cm x cm), for same depth.

Profiles

Three open beam depth profiles for square field sizes 10, 20, and 30 (cm x cm) at the depths of 10 and 20 cm were measured. The wedge profiles for maximum wedged field size of 30 x 40 cm were measured at 1.5 cm (dmax), 5 cm, 10 cm, and 20 cm. The off-axis-ratio (OAR) is the ratio of dose on a point at depth d, to the dose for the same field size and depth at the central axis. The OAR was measured at the beam profiles. The beam profiles were measured with high resolution (smaller step), minimum detector size (CC13 ionization chamber) and measured at different depths.

Output factors and scatter factors

The relative output factors were measured for square field sizes 3, 4, 5, 6, 8, 10, 12, 15, 18, 20, 25, 30, 35, and 40 (cm x cm) and normalized for 10 cm x 10 cm output. Two scatter factors Sc (Head Scatter Factor) and Sp (Phantom Scatter Factor) were needed. The Sc was measured with 3 cm diameter build-up cap with the ion chamber in an upright position. For those users of the data set for whom the treatment planning system required output factors at dmax, Sc,p was recalculated to the output defined at this depth using the ratios of percentage depth dose (PDD) values. Sp is obtained by dividing Sc,p by Sc for a given field size.

Bulk leaf transmission and back up jaw transmission

The bulk leaf transmission and back up jaw transmission were measured and entered into the treatment planning system.

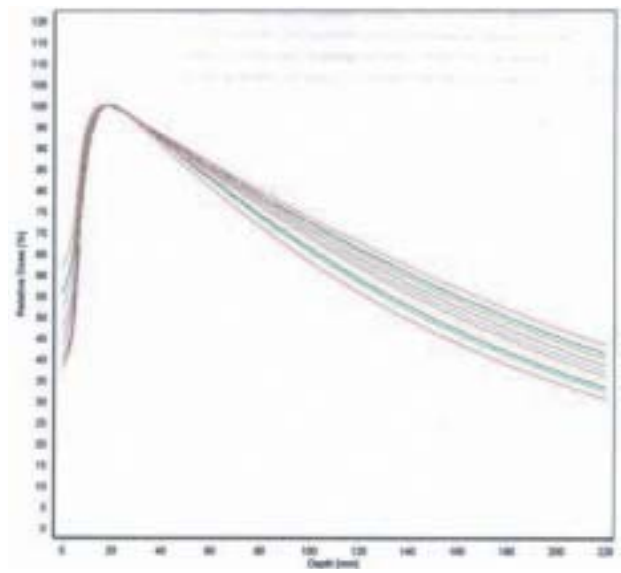

Fig 1. Percentage depth dose of respective open field sizes using CC13 pin-point ion chamber

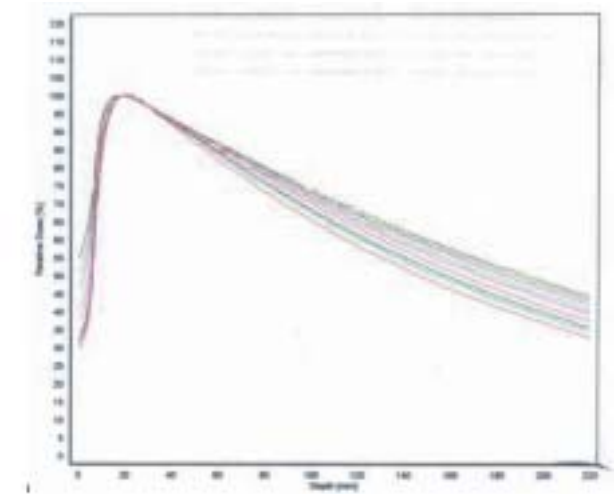

Fig 2. Percentage depth dose of respective wedged field sizes using CC13 pin-point ion chamber

RESULTS AND DISCUSSION

Dosimetric Analysis

The PDD data was measured with the CC13 pin-point ionization chamber detector for the different field sizes as shown in figure 1. The larger field sizes have higher PDD values for our dedicated system, the variation in PDD is limited to 3% between the 3 cm x 3 cm and 40 cm x 40 cm open field sizes at depth of 10 cm.

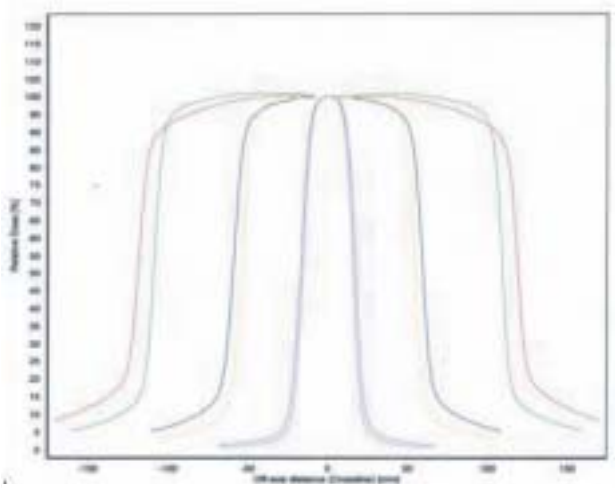

Fig 3a. Crossline dose profile

The percentage depth dose for wedged field sizes was measured and the variation found to be 4.2% between the 3 cm x 3 cm and 30 cm x 40 cm wedged field sizes at depth of 10 cm as shown in figure 2.

The OAR were computed from the beam profiles for 10 cm x 10 cm, 20 cm x 20 cm, and 30 cm x 30 cm field sizes at 10 and 20 cm depths in the x (crossline) and y (inline) directions and were found within ±0.2 mm. The OAR values entered in the treatment planning system were the average of the x and y profiles. The x and y profiles were as shown in figure 3a and figure 3b. The wedged profiles were measured at 1.5 cm, 5 cm, 10 cm, and 20 cm depths as shown in Figure 3c.

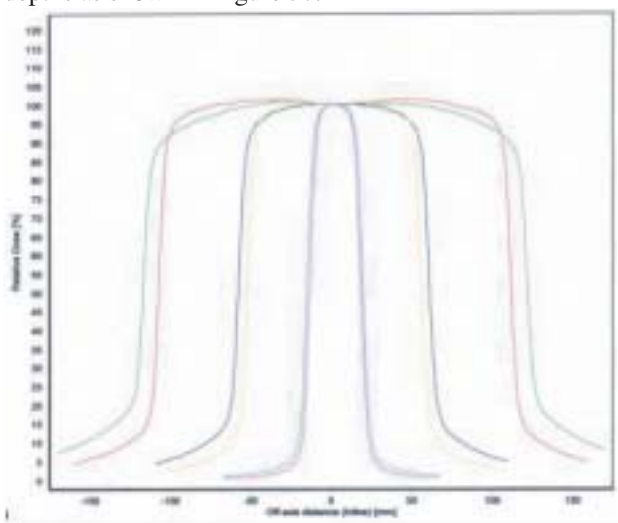

Fig 3b. Inline dose profile

The relative output factors (OF) for different field sizes was as shown in figure 4 and the scatter factor Sc(r) for open field sizes was as shown in figure 5.

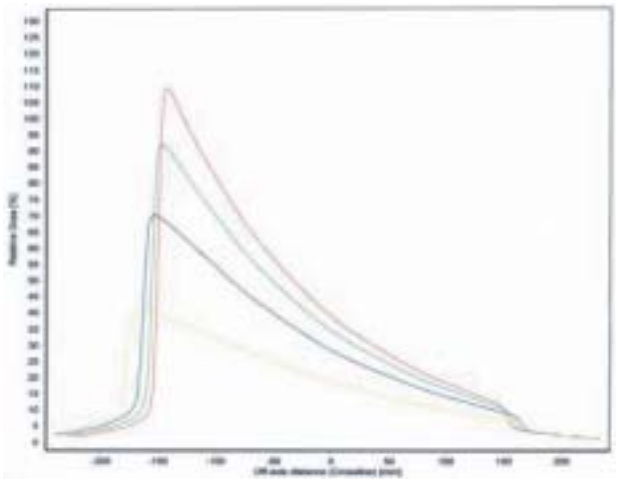

Fig 3c. The wedged beam profiles measured at 1.5 cm, 10 cm, and 20 cm depths

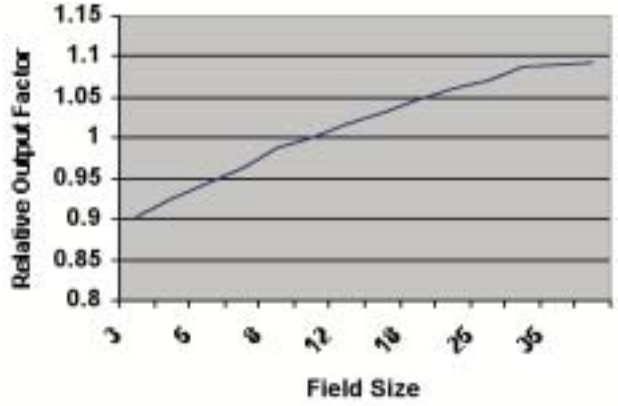

Fig 4. The relative output factors for various field sizes

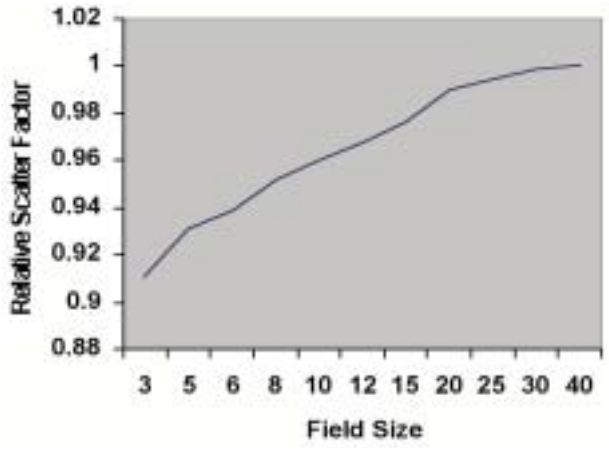

Figure 5. Scatter factors for open field sizes

Quality-assurance of dose calculation by measurements

Point dose calculations

The absolute point dose of the treatment plan was measured by using Head and Neck Cube supplied by Scanditronix Wellhofer. The dimension of this cube was 18 cm x 18 cm x 18 cm and had the facility to insert the ion chamber. The prostate plan was executed on this phantom and the point dose at the isocenter was calculated (TPS value). The same plan was executed on machine with same phantom by inserting 0.65 cc active volume Farmer type ion chamber (FC65-G). The dose at isocenter was measured. The calculated and the measured doses were compared and the variation was noted in table 1.

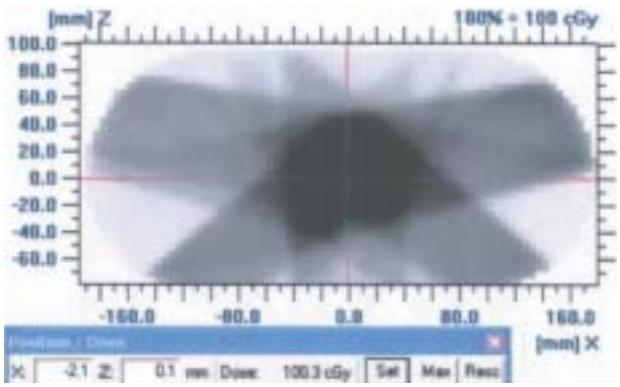

Fig 6A. Planned image generated from TPS for a prostate case

The deviations between the calculated dose, D_{calc}, and the measured dose, D_{meas} at a specific depth was given by $(D_{calc} - D_{meas})$ x 100% / D_{meas}. In those cases where the points were outside the penumbra or under a block, the results of the comparison were expressed relatively to the dose measured at the same depth, but on the central axis of the open beam, $D_{meas,cax}$ according to $(D_{calc} - D_{meas})$x100% / $D_{meas,cax}$ (7,8).

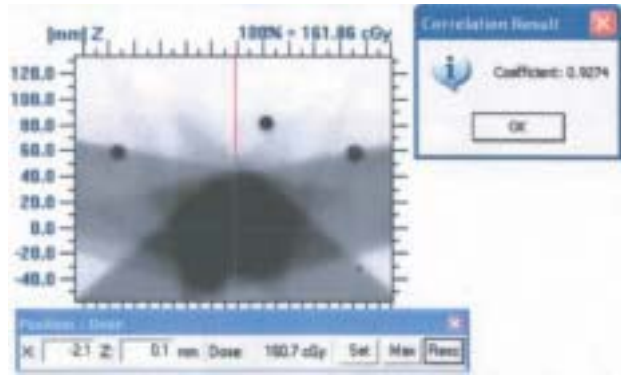

Fig 6B. Actual exposed image with Torso Phantom for a prostate case

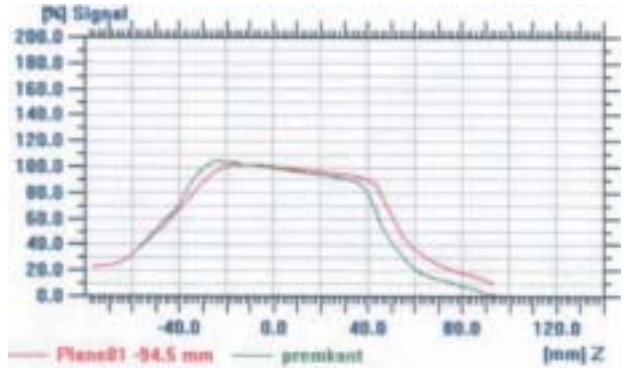

Fig 6C. Profiles comparison for prostate case

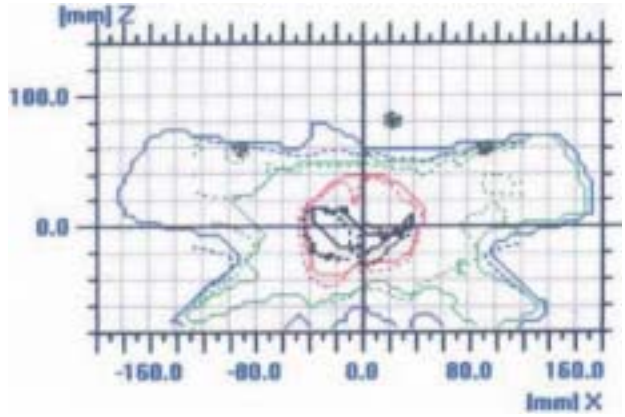

Fig 6D. Comparison of isodoses for prostate case

Isodose distribution comparison

Film measurement was performed for a prostate IMRT plan. Same prostate plan with seven non-coplanar beams were used. The Torso Phantom (Scanditronix Wellhofer's) was used to compare the calculated and the measured dose distributions. The film (Kodak EDR) was stacked in between the two slabs. Isodose distributions were measured using Kodak EDR film. The exposed film was scanned with Vidar Scanner and the distributions were seen through Omnipro IMRT Software. The comparisons between the calculated and the measured dose distributions were made within Omnipro IMRT Software system (9). The results for the prostate IMRT plan were as shown in figures 6A-6D.

From the figures shown in Figure 6, it is seen that the agreement between the calculated and the measured dose is within 2% in the high-dose region. For clinical patient specific QA we specify 3% dose difference and 3 mm distance acceptance scaling criteria (10).

The bulk leaf transmission and back up jaw transmission were 0.02% and 0.105%.

Treatment-planning system configuration parameters must be measured precisely. All the dosimetric tests have proved very useful and detected only minor deviations. The TPS calculated dose and the measured absolute dose should not deviate more than 3% to ensure safe treatment. It is necessary to maintain strict criteria to compare measured and calculated values. The patient pretreatment QA requires significant machine time for measurements and must be completed before treatment starts. In order to reduce patient pretreatment QA time, an independent monitor unit calculation program can be evaluated. The introduction of new analyzing tools, such as DTA (distance to agreement) or g (gamma factor), correlation coefficient can be useful to better quantify the comparison between measured versus calculated dose distributions (11,12). The implementation of IMRT must not be underestimated. Every institution should adopt a QA protocol. The QA protocol presented here has proved adequate, and with it we have had no patient complications attributed to IMRT delivery.

ACKNOWLEDGEMENT

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Table 1
Comparison of isocenter doses between the calculated the measured doses for 5 IMRT plans

Patient	Calculated (Gy)	Measured (Gy)	Difference (%)
1	2.043	2.055	0.58
2	1.385	1.357	-2.06
3*	2.73	2.68	-1.86
4	2.32	2.30	-0.86
5	1.605	1.637	1.95

* *Prostate patient*

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