Technical Note

Dose verification in carcinoma of uterine cervix patients undergoing 3D conformal radiotherapy with Farmer type ion chamber

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ABSTRACT

External beam radiotherapy (EBRT) for carcinoma of uterine cervix is a basic line of treatment with three dimensional conformal radiotherapy (3DCRT) in large number of patients. There is need for an established method for verification dosimetry. We tried to document absorbed doses in a group of carcinoma cervix patients by inserting a 0.6 cc Farmer type ion chamber in the vaginal cavity. A special long perspex sleeve cap is designed to cover the chamber for using in the patient's body. Response of ionization chamber is checked earlier in water phantom with and without cap. Treatment planning was carried out with X-ray computed tomography (CT) scan and with the chamber along with cap in inserted position, and with the images Xio treatment planning system. Three measurements on 3 days at 5-6 fraction intervals were recorded in 12 patients. Electrometer measured charges are converted to absorbed dose at the chamber center, in vivo. Our results show good agreement with planned dose within 3% against prescribed dose. This study, is a refinement over our previous studies with transmission dosimetry and chemicals in ampules. This preliminary work shows promise that this can be followed as a routine dose check with special relevance to new protocols in the treatment of carcinoma cervix with EBRT.

Key words: 3D conformal radiotherapy, cancer cervix, dose verification; farmer chamber, *in vivo* dosimetry, ionization chamber

Introduction

External beam radiotherapy (EBRT) is the most common standard treatment of choice in all non-metastatic stages of cancer of the uterine cervix. The ultimate check of the actual dose delivered to a patient in radiotherapy can only be achieved by using *in vivo* dosimetry[1] and this also serves as an important part of a quality assurance program that is recommended for improvement in quality of patient care.[2,3] Though *in vivo* dosimetry is not routinely carried out in all patients on routine basis, it has application to detect or assess clinically relevant differences between planned and delivered dose and its potential to identify probable errors in dose calculation, data transfer, dose delivery, patient set-up. In special procedures such as stereotactic radiotherapy or intensity modulated radiotherapy, in-phantom dosimetry methods are used as pre-treatment verification. Semiconductor diodes and thermo luminescent dosimeters (TLD) are used in the principal techniques for *in vivo* dosimetry.[4-7] Some other techniques of *in vivo* dosimetry employ metal oxide semiconductor field effect transistors, alanine, gels, plastic scintillators, radio chromic films, conventional portal films, or electronic portal imaging devices.[8,9]

These detectors offer disadvantage owing to periodic calibrations, correction for temperature, pressure, photon energy dependence, accurate positioning, and estimation of the photon fluence perturbation inside the patient, and therefore used in a limited number of centers. The most direct form of *in vivo* dosimetry is to physically place detectors inside the patient.[10] When detectors are introduced in

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readily accessible body cavities, such as esophageal lumen, rectum, vagina and bladder, it is possible to measure the *in vivo* dose,[10,11] and use of an insulated ion chamber for on line dose verification was first reported[12] in rectal cavity.

Earlier we reported chemical dosimeter (ferrous sulfate-benzoic acid–xylenol orange [FBX] aqueous chemical dosimeter system) ampules in vaginal cavity to record doses, and also used transmission measurements with ion chamber in a group of carcinoma cervix patients.[13,14] We wanted to check the feasibility of using thimble chamber used for beam level dosimetry, for measuring absorbed doses in vivo, in the patients treated with three-dimensional conformal radiotherapy (3DCRT), as a dose verification method.

Materials and Methods

Patients

A total number of 12 patients with carcinoma of uterine cervix were selected. An informed consent was taken from the patients about the *in vivo* dosimetric procedure by the physician. All the patients received treatment with linear accelerator with 3DCRT.

Detector used for dose verification

An absorbed dose calibrated Farmer type ionization chamber (IC) (FC65-G, IBA Dosimetry GmbH) was used to record doses in vivo. A specially designed perspex protection cap (total length 13cm and 1.5cm diameter) with an extended coverage till the end of aluminum stem of the IC [Figure 1] fabricated locally ensures better insulation during patient dosimetry by insertion into the vaginal cavity. Absolute dose measurements were conducted with IC in water phantom under source to axis distance (SAD) geometry, to find out response, depth dose dependency and field size variations, with and without the perspex cap.

Simulation and target volume delineation

All patients were immobilized with vacloc device (from M/s Klarity Medical, USA) in supine position with the hands placed overhead. During CT simulation procedure, ionization chamber with locally fabricated perspex cap covered with a thin sheath of rubber material (latex rubber) was inserted in the vagina (natural body cavity), maintaining all the necessary aseptic conditions for all patients, with head towards gantry. Scanned serial computed tomography (CT) images were exported to Focalsim contouring station (M/s Elekta Ltd., Crawly, UK) via digital imaging and communications in medicine (DICOM) network. The contouring of tumor volumes and normal structures was done by radiation oncologists. The clinical target volume (CTV) encompassed the gross tumor volume (GTV) with 5 mm margin together with pelvic nodal basins up to the bifurcation of inferior vena cava, was created. The planning target volume (PTV) was generated by adding 5 mm margin to the CTV to account for inter fractional geometric positional uncertainties. The region of IC was contoured in all transverse slices with an additional margin of 5 mm to account for probable inter fractional positional changes during the course of treatment.

Treatment planning and therapy execution

CMS XiO® (Elekta Ltd, Crawly, UK) version 4.80.02 treatment planning system (TPS) utilizes Clarkson, convolution, superposition and fast superposition algorithms. The contoured images were transferred to TPS for beam placement and dose calculations by using superposition algorithm. A set of four beams with gantry angles 270°, 0°, 90° and 180° were placed and field in field technique was used as and when required to reduce the hot spots, and a 3DCRT plan was generated. A dose of 50 Gray in 25 fractions was prescribed to PTV which was normalized to the 100% isodose line. The mean dose calculated by TPS in the region of IC from the dose volume histogram (DVH) was noted. Figure 2 represents the position of IC in the planning CT in transverse, coronal and sagittal planes with DVH. The 3DCRT plan was evaluated, finalized by the radiation oncologist and was exported to record and verification system (MOSAIQ®) for scheduling and execution. The lateral and anterior digitally reconstructed radiograph (DRR) images were exported to electronic portal imaging station (iViewC-camera based) for positional verification before treatment execution.

All patients received 3DCRT with Elekta linac 6MV Photon energy, motorized wedge, 40 pairs of multi leaf

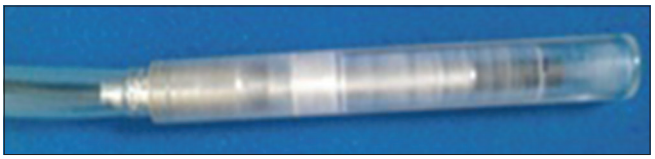

Figure 1: Locally fabricated perspex protection cap with an extended coverage till the end of aluminum stem of the ionization chamber

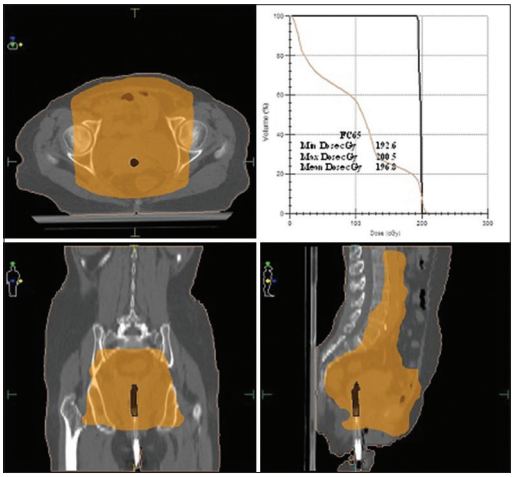

Figure 2: Isodose coverage around ionization chamber in the in transverse, coronal, and sagittal planes with dose volume histogram

collimator (MLCi2) with leaf thickness of 1cm projected at 100 cm isocenter and electronic portal imaging device (iViewC). Machine is calibrated for 1cGy/MU at iso center at a dose rate of 350 MU/min.

Prior to treatment execution, verification of patient's treatment setup under LINAC was checked with iViewC. A 3mm margin of translational (x, y, and z) errors were permitted and necessary couch shifts were applied, as and when required. The scheduled 3DCRT treatment was subsequently executed. Figures 3a and b show the portal images of anterior and lateral treatment fields.

Dose measurements

Treated patients had inserted IC in vaginal cavity as described during simulation. Temperature of patient's body is taken at the time of treatment. Electrometer (Dose1, Iba) readings were recorded in the proforma (in nano coulombs, nC) during treatment execution. With necessary correction factors ($N_{D,w}$, temperature of body, pressure, polarity, beam quality & saturation) the absorbed dose (in Gy) at the dosimeter locations are recorded. Three measurements were taken for each patient with scheduled gap of 5-6 fractions intervals. Mean dose of all three measurements were taken to compare with the planned dose at the reference point of the detector.

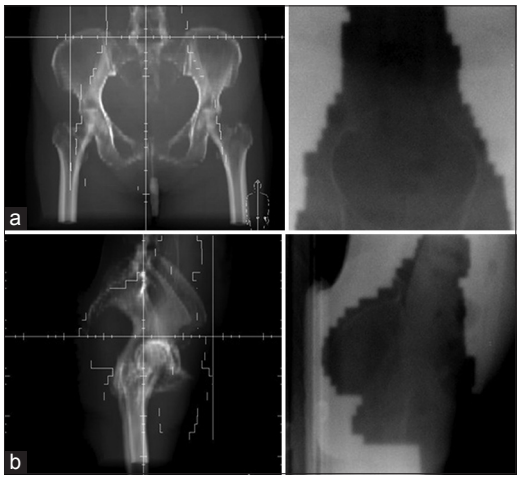

Figure 3: (a) Anterior treatment portal image. (b) Lateral treatment portal image

Results

The median age of studied patients was 58 years. Of the 12 subjects, five had stage IIB and seven had stage IIIB disease. The measured doses with IC in water phantom in SAD geometry, field size and depth dose dependency with and without prototype perspex cap is shown in Table 1. It was observed that there was no significant difference in the absolute doses with water medium around, with or without perspex cap used for patient's measurements. Corrected measurements at 10 cm depth also were in good agreement with TPS dose values used for patient's treatment plans using tissue maximum ratios. Table 2 shows the estimates of absorbed doses in vivo, for all the 12 patients. Mean doses with IC recorded in patients were in good agreement with planned doses in these patients by treatment planning system (Mean DVH at reference point of measurement). The percentage deviation of measured dose (with IC) with calculated dose by TPS (from DVH) of individual patients ranges from -3.05 to 2.96%. Table 3 showed the Comparison of results (mean % deviation with standard deviation for measured vs calculated dose) against our previous reports.[13,14]

Discussion

An effective way of checking the quality of the entire dosimetric procedure, from the accurate positioning of patient to the performance of the treatment machine, is to take absorbed dose measurements on the patient and, when possible, in natural body cavities.[15] Our present work has brought out an effective way of documentation of absorbed dose in clinical radiotherapy, which has application where such cavities exist. Also, 0.6 cc Farmer type ion chambers are available in all medical physics departments, and therefore any verification methods could be designed with this detector. As field sizes used in pelvic treatments are broad enough to give an accurate estimate of central doses, this method could be adopted in intensity modulated treatments

Table 1: Absolute dose (Gy) measured measured with IC for different field sizes and depths with and without perspex cap using variable depth water phantom under SAD condition

Depth (cm)	*8*			*10*			*12*			*14*		
FS (cm×cm)	*With cap*	*Without cap*	*% dev.*	*With cap*	*Without cap*	*% dev.*	*With cap*	*Without cap*	*% dev.*	*With cap*	*Without cap*	*% dev.*
5×5	1.99	2.00	−0.50	2.03	2.04	−0.49	2.01	2.02	−0.50	2.02	2.03	−0.49
10×10	2.00	2.01	−0.50	2.01	2.02	−0.50	1.99	2.00	−0.50	2.01	2.02	−0.50
15×15	2.03	2.04	−0.49	2.06	2.04	0.98	2.03	2.01	1.00	2.03	2.04	−0.49
20×20	2.01	2.02	−0.50	1.99	1.98	0.51	2.01	2.00	0.50	1.99	1.98	0.51
25×25	2.06	2.04	0.98	2.01	2.02	−0.50	2.02	2.03	−0.49	2.01	2.02	−0.50
30×30	1.99	1.98	0.51	2.02	2.03	−0.49	1.98	1.99	−0.50	2.06	2.04	0.98

IC: Ionization chamber, SAD: Source to axis distance, FS: Field size

Table 2: The % deviation of measured dose (with IC) with calculated dose by TPS (from DVH)

Patient no.	*Dose (in gray)*		*% deviation*
	Calculated by TPS	*Measured with IC*	
1	2.01	2.05	−1.99
2	1.98	2.04	−3.03
3	2.05	1.99	2.93
4	1.97	2.03	−3.05
5	1.98	2.04	−3.03
6	2.06	2.02	1.94
7	1.99	2.02	−1.51
8	1.99	2.04	−2.51
9	2.02	2.03	−0.50
10	1.96	1.99	−1.53
11	2.03	1.97	2.96
12	2.03	2.07	−1.97

IC: Ionization chamber, DVH: Dose volume histogram, TPS: Treatment planning system

Table 3: Comparison of *in vivo* dose estimates with previous reports (mean % deviation with SD for measured vs calculated dose)

IC (present study)	*FBX chemical*	*IC transmission*
0.94±2.28%	0.96±4.94%	0.17±0.81%

IC: Ionization chamber, FBX: Ferrous sulfate-benzoic acid-xylenol orange, SD: Standard deviation

for prostate cancers where placement of dosimeter in rectum is feasible. Entrance and exit dose measurements with diode or TLDs are common in total body irradiation with photons and such measurements have been done prostate, bladder and parotid gland tumor treatments. Table 3 highlights that our present work has solved the problem in reducing the deviation encountered in our previous studies,[13,14] because during that period of time, treatments were based on simple plans with measured inter-field separations and there were no documented methods for DVH averaging at the position of detectors. As 0.6 cc chambers average doses across its air volume, smaller IC detectors could be employed if segmental small fields are encountered in treatment execution. As the IC is positioned at the measuring position at the time of simulation, taken into account for pixel based treatment planning, the reproducibility is well ensured, and therefore we confirm that our measured doses are fairly accurate enough for documentation.

Conclusions

Dose verification before starting and during the course is becoming essential part of modern radiotherapy. Present study evaluated the applicability of a conventional ionization chamber for performing *in vivo* dose measurements in patients of carcinoma of uterine cervix undergoing 3DCRT. As a verification procedure this could be incorporated in clinical trials if it is warranted. Future work is needed to compare this simple method with well established small field dosimeters like diamond detectors.

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