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Comparison of Prescribed from Delivered Dose to Cancer of Cervix Patients Treated by Theratron Equinox 80 cm Source-to-Axis Distance (SAD) Technique at Ocean Road Cancer Institute in Tanzania

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Abstract

The aim of the present study was to investigate deviations between prescribed from delivered dose for cervical cancer patients treated at Ocean Road Cancer Institute using Equinox 80 Tele-cobalt machine. In this work, anterior-posterior (AP) and posterior-anterior (PA) fields using Source-to-Axis Distance (SAD) technique was used. Measurements of entrance doses were taken using calibrated diode detector in three groups of patients. In group 1, only 15 patients out of 31 curative intent patients received doses lower than ± 5% of 2 Gy as compared to the prescribed dose. In group 2, 1 measurement was done for 9 patients who received palliative single dose of 10 Gy and 2 patients out of 9 received doses within the range of ± 5% of the prescribed dose. In group 3, 1 daily measurement was done for 12 patients who were prescribed a curative dose of 50 Gy in 25 fractions. The maximum observed deviation was + 25.08%, while that of minimum was – 0.59%. Since significant deviations between prescribed and delivered doses exist, there is a need to conduct another study using both patient and machine related factors to refine the problem of high dose deviations among the patients.

Keywords: Tele-cobalt machine, *in-vivo* dosimetry, measured and delivered dose, cervical cancer, diode detector.

Introduction

External beam radiation therapy plays a vital role in the management of carcinoma of the cervix and is the standard treatment of choice of this type of cancer (Srinivas et al. 2014). The ability to deliver the precise tumour dose in external beam radiation therapy depends on several factors; the most significant include exact dose calibration, accurately determined depth dose, off-axis dose characteristics, and knowledge of the precise patient geometry used during irradiation (Yorke et al. 2005). The ultimate check of the real dose delivered to a patient in radiotherapy can only be achieved by using *in-vivo* dosimetry (Tunio et al. 2011) and serves as an essential part of a quality assurance program. Beside the importance of

in-vivo dosimetry in detecting clinically relevant differences in radiation therapy, it is not carried out on routine basis at Ocean Road Cancer Institute (ORCI). It is therefore, this study aimed to use *in-vivo* dosimetry using diode detector to investigate the percentage dose deviations between prescribed and delivered doses for cervical cancer patients who received external beam radiotherapy using Equinox 80 tele-cobalt machine (from Best Theratronics, Ottawa, Canada) at Ocean Road Cancer Institute (ORCI).

Materials and Methods

Ethical consideration

Ethical clearance was obtained from the University of Dar es Salaam Research Ethics Committee (UDSM-REC). The permission to conduct this study was obtained from authorities of ORCI through its research, publication and ethics committee before the commencement of this study.

Dose measurements

All entrance dose measurements were performed on patients receiving pelvic radiotherapy for cervical cancer. This work concentrated only on cervical cancer because more than 34% of all new cancer cases at ORCI fall in this category (Amour et al. 2019). Data of cervical cancer patients' doses was obtained from 3rd September 2018 to 20th February 2019. The prescribed dose for curative intent for cervical cancer patient at ORCI is 2 Gy per fraction, while that of palliative intent patients is 10 Gy per fraction. Therefore, the total prescribed treatment dose of curative intent patient which is more relevant for curability is 50 Gy in 25 fractions. According to ORCI treatment protocol, the delivered dose was obtained by specifying both machine and patient's parameters that were used during treatment planning. Since ORCI uses Co-60 teletherapy machine, therefore, Tera six Simulator which was installed in 2011 by UJP PRAHA is used for taking two-dimension (2-D) images to help in treatment planning procedures. Since it is not possible to insert radiation detector in patients' body, dose delivered to the tumour was estimated using entrance dose (D_{ent}). Each patient was then placed in supine position on the treatment coach and diode was placed at the centre of the radiation field on the patient skin in order to measure the entrance dose. For the entry point, the entrance dose D_{ent} which is defined as the dose at d_{max} from the incident plane on the axis of the beam was calculated using Equation (1) (Heukelom et al. 1991):

$$D_{ent} = R_d.F_c.\Pi CF_i \qquad (1)$$

where; R_d is diode reading, F_c is calibration factor and CF_i represents the i^{th} correction factors.

Calibration of diode detector

Dosimetric diode IVD, manufactured by Sun Nuclear Corporation, Melbone, FL, USA model 1131 was calibrated against an ionization chamber (model W- 30001 with serial number 1205) connected to the electrometer (model UNIDOS with serial number 20359 from PTW Freiburg) during the calibration process. The methodology used for calibration of diode followed the IAEA, TRS-398 protocols for absorbed dose determination in external beam radiotherapy. By using Source-to-Axis Distance (SAD) technique, measurements were taken while the diode placed on the top surface of water phantom (dimensions: 30 cm × 30 cm × 30 cm) was kept at 70 cm in such a way that source of Equinox 80 teletherapy unit to ionization chamber distance was 80 cm. Three readings are taken each for one minute for reference field size of 10 cm × 10 cm. The absorbed dose to water at reference depth was then obtained by using Equation (2), (IAEA, 2000):

$$Dw = M_Q N_{Dw} K_{pol} K_s K_Q K_{TP} \qquad (2)$$

where;

M_Q is the reading of the dosimeter positioned in accordance with the reference conditions given by the manufacturer.

N_{DW} is absorbed dose to water calibration factor for given electrometer and ionization chamber.

K_{pol} is a factor to correct for any departure of the reading due to changing the polarizing voltage from its value at calibration.

Ks is a factor to correct for the lack of saturation due to recombination.

K_Q is the correction factor for energy and for Co-60 is taken as 1.

K_{TP} is a factor to correct for departure of air density from reference conditions.

Since the chamber was kept at a depth of 10 cm which is the reference point, the output readings obtained from equation 2 would be at 10 cm depth. To obtain the output at d_{max} as a function of field size, the above formula was divided by tissue-air-ratio at 10 cm depth for SAD.

This was done to check for the safety purpose before the dose is delivered to the patients.

Treatment time

Treatment time required to deliver a prescribed dose (T) for each patient was calculated using Equation (3) (Khan 2015);

$$T = \frac{D_p}{D_r \times S_f \times TAR} \qquad (3)$$

where: D_p and D_r represent prescribed dose and dose rate, respectively, while S_f is total scatter factor and TAR is the tissue-air-ratio obtained from Storchi and van Gasteren (1996) and Wamied (1999), respectively.

The control console was used to set the irradiation time for each patient and diode recorded the respective readings. Gantry and collimator angles were rotated and set at zero degrees for entrance dose measurements in order to match with the obtained simulation parameters. The combination of anterior-posterior and posterior-anterior open beam two fields' Source-to-Axis Distance (SAD) technique was used in this work for treatment of both curative and palliative intent patients. This procedure was done for 43 curative intent patients and 9 palliative intent patients.

Results

A total of 52 cervical cancer patients of different depths and field sizes were treated at ORCI for both curative and palliative intent cases. The numbers of patients with curative intent were 43 with prescribed dose of 2 Gy per fraction. 12 patients out of 43 (referred to as group 3) were treated using 25 fractions in order to complete a total prescribed dose of 50 Gy. Out of 52 cervical cancer patients, there were only 9 (group 2) palliative patients with prescribed dose of 10 Gy per fraction. With this prescription, a single dose of 10 Gy by delivering 5 Gy in anterior-posterior and posterior-anterior (AP and PA) fields were given for all palliative patients. The diode dose reading used to calculate the entrance dose for fraction 1 for 31 patients are compared with prescribed dose calculated using patient's and machine parameters (depth and treatment field). For the sake of comparison, the percentage deviations of entrance doses from prescribed doses are listed in Table 1. From the literature, curability requires the percentage deviation to be within ± 5% (ICRU 2016, IAEA 2000, Thwaites 2013). According to this specification, only 15 patients (48%) out of 31 listed in Table 1 were expected to have relatively favourable prognosis because the deviations ranged from 0.73% for patient # 7 and patient # 12 to 4.35% for patient # 14.

Like in the case of curative intent patients, Table 2 shows the percentage deviations between entrance and prescribed doses for 9 palliative intent patients each treated with a single dose of 10 Gy.

In principle, curability of cancer of the cervix depends on the overall dose delivery accuracy. This has been computed by summing delivered doses of each fraction. The comparison of deviations of total prescribed and total delivered doses for curative patients are presented in Table 3. According to the earlier dose delivery accuracy specification, only 4 out of 12 patients (~33%) were expected to have favourable prognosis because their deviations ranged from –0.59% for patient # 49 to 4.94% for patient # 41. On the other hand, 8 patients were expected to have poor

prognosis because of large range of percentage dose deviations. For patient # 45, the deviation was 5.59%, while that of patient # 46 was 25.08%.

Table 1: Percentage deviation dose calculated from 31 curative intent cervical cancer patients in the first fraction only

Patients ID	Diode dose reading (Gy)	Entry dose measurement (Gy)	Calculated prescribed dose (Gy)	% deviation of the dose from calculated dose
Patient # 1	1.61	1.28	1.33	3.75
Patient # 2	1.56	1.24	1.37	9.48
Patient # 3	1.38	1.11	1.37	18.95
Patient # 4	1.98	1.57	1.40	–12.14
Patient # 5	2.25	1.68	1.42	–18.30
Patient # 6	2.06	1.50	1.41	–6.38
Patient # 7	1.70	1.36	1.37	0.73
Patient # 8	1.80	1.34	1.30	–3.08
Patient # 9	1.67	1.32	1.36	2.94
Patient # 10	1.76	1.40	1.38	–1.45
Patient # 11	1.70	1.27	1.37	7.30
Patient # 12	1.72	1.36	1.37	0.73
Patient # 13	1.77	1.42	1.39	–2.16
Patient # 14	1.77	1.32	1.38	4.35
Patient # 15	1.67	1.24	1.37	9.50
Patient # 16	1.91	1.52	1.41	–8.03
Patient # 17	2.03	1.45	1.43	–1.40
Patient # 18	1.70	1.27	1.37	7.92
Patient # 19	1.88	1.50	1.38	–8.69
Patient # 20	1.70	1.35	1.37	1.45
Patient # 21	1.64	1.31	1.36	3.72
Patient # 22	1.70	1.35	1.37	1.99
Patient # 23	1.68	1.25	1.38	9.42
Patient # 24	1.67	1.35	1.38	2.17
Patient # 25	1.75	1.41	1.38	–2.17
Patient # 26	1.77	1.43	1.38	–3.62
Patient # 27	1.57	1.27	1.35	5.93
Patient # 28	1.86	1.50	1.37	–9.49
Patient # 29	1.71	1.26	1.39	9.35
Patient # 30	1.69	1.45	1.38	–5.07
Patient # 31	1.90	1.53	1.38	–10.87

Table 2: Percentage dose deviation observed from expected dose in 9 cervical cancer patients treated with palliative intent

Patient ID	Diode reading measurements (Gy)	Entrance dose (Gy)	Calculated dose (Gy)	% deviation of measured from prescribe dose
Patient # 32	8.68	6.37	6.89	7.50
Patient # 33	8.50	6.24	6.89	9.40
Patient # 34	7.73	5.68	6.85	17.21
Patient # 35	8.32	6.28	7.04	10.83
Patient # 36	9.15	6.72	6.94	3.23
Patient # 37	8.35	6.22	6.89	9.24
Patient # 38	8.85	6.41	6.89	7.08
Patient # 39	7.63	5.84	6.66	12.47
Patient # 40	8.21	6.61	6.85	3.56

Table 3: Percentage deviation dose calculated from 12 curative intent cervical cancer patients in 25 fractions

Patient ID	First fraction diode dose reading (Gy)	Total entrance dose for 25 fractions (Gy)	Total calculated dose for 25 fractions (Gy)	% deviation of the total doses
Patient # 41	1.69	32.78	34.48	4.94
Patient # 42	1.6	30.18	34.48	12.47
Patient # 43	1.53	28.03	35.71	21.51
Patient # 44	1.7	33.81	34.25	1.27
Patient # 45	1.79	32.78	34.72	5.59
Patient # 46	1.5	25.64	33.33	25.08
Patient # 47	1.85	36.87	34.96	-5.45
Patient # 48	1.49	27.61	33.56	17.73
Patient # 49	2.45	35.67	35.46	-0.59
Patient# 50	1.63	32.66	34.25	4.64
Patient# 51	1.71	30.75	34.25	10.23
Patient# 52	1.88	40.49	35.71	-13.37

Discussion

In practice, *in-vivo* dosimetry of the measured dose from prescribed has been used as method to detect errors in radiation therapy and to assess the dose delivery accuracy of radiotherapy machine (Pokoo et al. 2015, Tunio et al. 2011, Yusuph et al. 2016, Rodríguez et al. 2008). As indicated in Table 1, only 15 patients (48%) out of 31 had deviations within the acceptable range of ± 5% in the first fraction of their measurements. In comparison, a study conducted by Yusuph et al. (2016) at ORCI to assess dose delivery accuracy of the same tele-cobalt machine for breast cancer patients treated with curative intent, 32 out of 50 patients (64%) were reported to have percentage deviation within the range of ± 5% in the first fraction. Since both studies used ORCI's Theratron Equinox 80, it is evident that the higher accuracy reported in the previous studies may not be attributed exclusively to the radiotherapy machine. The observed difference in dose deviations is most likely attributed to other causes including patient related factors as already pointed out by other authors (Thwaites 2013, Pokoo et al. 2015). Since it is unlikely that the machine is the main source of errors, there is an urgent need to investigate the sources responsible for such large deviations of the measured from prescribed doses. With the information gathered from such investigations, it would be possible to specify more precisely the purpose of investigating dose delivery accuracy using a

single dose fraction. This requirement is not essential in the palliative treatment, especially when negative (under dose) errors are not observed as was the case in this study.

In-vivo dosimetry for cervical cancer patients who received a palliative treatment was also done and the results of percentage deviations between prescribed and delivered dose are presented in Table 2. Since none of the 9 palliative patients was under dose, the observed positive percentage dose deviations could be beneficial knowing that these were palliative patients who need this opportunity for reducing suffering and death from cervical cancer in Tanzania. Beside these results, it is also very important to improve screening process and early detection to reduce morbidity and mortality from cervical cancer in Tanzania.

From table 3, it can be observed that 2 out of 12 patients had negative deviations outside the specified range, while 6 patients had positive deviations outside this range. Higher deviations in this group of patients could be due to planning calculations, patient movement during treatment, wrong patient set-up and other machine related factors like fluctuation of power. According to ICRU report 50 specifications (Landberg et al. 1993, ICRU 2016), more than 50% of the patients treated would not be cured. Incidentally, this value corresponds to below 40% of curability of cancer of the cervix already reported in the literature for the sub-Saharan countries (Thwaites 2013, Maranga et al. 2013, Nelson et al. 2016). Curability could be also influenced by dose prescription which does not specify the amount of dose delivered to the tumour mass. Since the specification of dose delivery accuracy is related to the dose delivered to the tumour mass, there is a need for dose prescription to be modified to have a closer relationship to the dose requirement for curability. In this case, investigations of the factors responsible for dose deviations associated with dose planning based on 2D images are urgently needed for subsequent development of methods to improve dose delivery accuracy. However, unless the prescribed dose related to the dose needed to eradicate the tumour mass, dose delivery accuracy cannot be evaluated in terms of ±5% deviations.

Conclusion

In this study, the determination of dose deviations between prescribed and delivered doses was done using a diode detector. A high degree of deviation was observed in some patients. This requires the determination of prescription dose and treatment protocol to be modified to have a closer relationship to the dose requirement for curability for patients treated using Equinox 80 tele-cobalt machine at ORCI.

Conflict of interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing up of this paper.

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