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Determining rectal dose through cervical cancer radiotherapy by 9 MV photon beam using TLD and XR type T GAFCHROMIC® Film

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Background: The goals of the present research were to investigate the rectal dose during four chosen techniques of cervical cancer radiotherapy and to examine how accurately the treatment planning represents dose measurements, and it's practicality for routine use as well as, to determine the homogeneity of dose in tumor volume. *Materials and Methods:* The study was carried out using a Nepton 10-PC unit and a Rando phantom. The equipments which were used for dose determination were a Radiochromic densitometer with GAFCHROMIC® film (XR type T), and a thermo-luminescent dosimeter (TLD) reader system with TLD chips for rectal and target volume dose determination. Several techniques of external beam radiation therapy such as two-field (AP-PA), three-field and four-field with equal tumor dose and with equal applied dose were planned. *Results:* The maximum dose received by rectum was caused by two-field technique. The results of two dosimetry types were compared with each other as well as with the treatment planning, however, no statistically significant difference was observed between them (p > 0.05). In three-field, four -field with equal tumor dose and four-field with equal applied dose, rectal dose was lower, respectively 26.17%, 33.75% and 16.47%, than tumor dose. Conclusion: This study showed that dosimetry using TLD and film during radiotherapy could have a useful role as a predictor of choosing appropriate technique for preventing future rectal complications. Dose limitation to the rectum could possibly be achieved by using three-field and four-field techniques with equal tumor dose while maintaining a high dose to the tumor. **Iran. J. Radiat. Res., 2008; 6 (3): 129-134**

Keywords: *Rectal dose, TLD, XR type T film, cervix cancer.*

INTRODUCTION

Nowadays cancer is one of the major causes of human mortality in the world. Cervical cancer is among the common types. Radiotherapy plays an important role in the treatment of cancers. It treats cancer by using high-energy rays which destroy the cancer cells, while doing as little harm as possible to normal cells. Radiotherapy for cancer of the cervix can be given externally or internally, and often as a combination of the two. It is usually given if the cancer has spread beyond the cervix and is not curable with surgery alone and may also be used after surgery if there is a high risk that the cancer may come back. It is often given in combination with chemotherapy. Conformal beam therapy is best utilized for tumors that are geometrically defined, isolated, and hard to treat surgically. Radiotherapy of cervix carcinoma often results in high doses to surrounding structures, such as rectum and bladder. Therefore, these organs should be closely monitored. The late complications manifesting on these organs, as a result of radiotherapy, can lower the therapeutic ratio and significantly decrease patient quality of life (1-2-3) .The most important treatment related factors that could lead to creation of late complications on rectum include total dose to the rectum and the volume of irradiated rectum. Of those, the

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dose delivered to the rectum is particularly important [4].

Researchers try to develop new treatment techniques by which increasing patients' survival and concomitantly minimizing morbidity. Apart from accuracy of the dose at the point concerned, a uniform dose distribution within the target volume is also crucial for successful radiotherapy.

It is generally accepted that variance in the dose delivered to the patient should not be greater than 5% at the reference point [5]. More recently, a tolerance of 3.5% has been suggested [6]. Subsequently, the International Commission on Radiation Units and Measurements (ICRU) report No. 50 has recommended dose homogeneity of between -5% and +7% of the prescribed dose throughout the planned target volume (PTV) [7]. Furthermore, treatment planning for prostate cancer is complex because of the close vicinity of vital organs, i.e. rectum and bladder.

The goal of the present study was to compare the two different dosimetry methods (TLD and XR type T film) with each other, and also with the treatment planning to know the level of accuracy and to reach the optimum treatment technique among the commonly used techniques in hospitals with low risk to rectum in cervical cancer patients treated by external beam radiotherapy.

MATERIALS AND METHODS

This study was performed at Emam Reza Hospital, Mashhad University, Iran. Alderson Rando phantom (reference man) was used as a patient for determining the received dose. The phantom is transected horizontally into 2.5 cm thick slices. Each slice has holes which are plugged with bone-equivalent, soft-tissue or lung tissue-equivalent pins which could be replaced by TLD holder pins. The holder pins are ordered separately [8]. Figure 1 shows an Alderson Rando phantom.

Figure 1. Alderson Rando phantom.

The Rando phantom was placed on the linear accelerator table. Dose mapping technique was used to investigate the dose distribution throughout a planned target volume (PTV) and organ at risk (rectum) in a phantom exposed to 9 MV photon beam generated by a Nepton 10-PC linear accelerator (Poland), with similar treatment conditions. Several techniques of external beam radiation therapy such as two-field (AP-PA), three-field and four-field were planned. Three-field technique consisted of two lateral wedge fields and one anterior field. Four-field arrangement or box technique had two methods. The first method used equal applied dose, and the second one used equal tumor dose. Treatment fields were simulated using a simulator (Simax, Poland).

The dosimetry results based on treatment planning, TLD and XR type T GAFCHROMIC® film measurements were compared with each other. Treatment planning was done using a TPS (Alfard, Poland).

Multi layer XR type T film detector which has high sensitivity for detection of radiation used in this investigation. In this kind of film, the active layer is sandwiched between the two sheets of polyester. In the type T film, both polyester substrates are transparent. The active layer is about 28 microns thick with a physical density of 1.75 g/cm^3. These film types are designed and manufactured by International Specialty Products (ISP), Inc. (Wayne, NJ) and are available in sheet sizes of 5 inches × 5 inches. The color of XR type T films turn from orange to brownish-black, depending on the level of exposure (9-10). This film was handled in accordance with the precautions recommended in TG-55 (11). A densitometer (Model 07-443, Victoreen Co., Nuclear Associates) was used to measure the optical density of the exposed films. The optical densities of the film pieces were measured 24 hours after irradiation.

A TLD reader system (Harshaw model 3500 manual reader), together with some TLDs of LiF: Mg:Ti (these are commonly called TLD-100), were used for dose measurement. TLDs were supplied by Harshaw Co. in the size of 1 mm × 3 mm × 3 mm. To calibrate TLD-100 chips, they were exposed to doses similar to those expected to be measured in research (12-13). For annealing procedures the TLDs were heated to 400 °C and maintained at that temperature for 1 hr, followed by 100 °C for 2 hr then cooled to room temperature.

For dose measurement, TLDs were inserted by vacuum tweezers in a sequential order of labeled TLDs at the pre-determined sites in slice 31 of the phantom. The position was determined by the fact that the cervix is the lower part of the uterus. Figure 2 shows the radiograph of the pelvis of the phantom. Five TLD chips were used at each measurement site. The doses were delivered based on the calibrated linac output, and measured in accordance with the TG-51 protocol (14).

Statistical analysis

Analysis of the obtained results was done by using SPSS (Statistical Package for Social Science; version 14.1) software. Statistical analysis of the rectum and cancer volume (cervix) data was done by Independent Samples *t-test* (SPSS Inc.). For determining the best technique (from the rectum measured dose), statistical analysis were preformed using one-way ANOVA and LSD test. P values less than 0.05 were considered as statistically significant difference.

RESULTS

Before measurements were carried out, the isodose distribution was generated by the TPS. The plan was optimized to cover the whole PTV by 100 % isodose line focusing the slice. The calculated dose for rectum was as follows: 2.055 Gy with two-field, 1.238 Gy with three-field, 1.582 Gy with box with equal applied dose and 1.517 Gy with box with equal tumor dose.

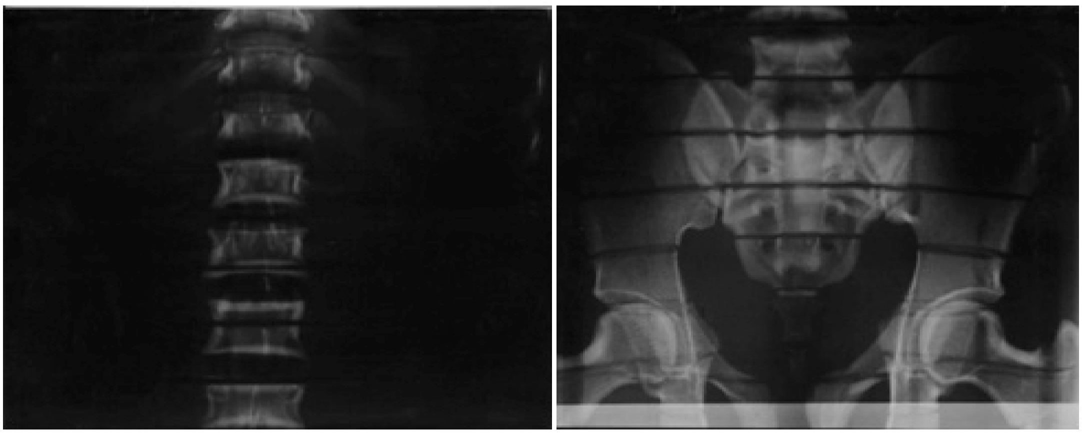

Figure 2. Radiograph of the pelvis of the phantom.

The results obtained from the TLD and film dosimeters were grouped according to their locations/points of interest in the irradiation volume.

Five points were selected for dosimetry on the phantom slice (slice 32). Figure 3 illustrates the situation of the chosen points. A, B, C and D illustrate points which were chosen in tumor volume and R, for rectum. The experiments were repeated 5 times, and the results are presented as the average of the 5 data sets.

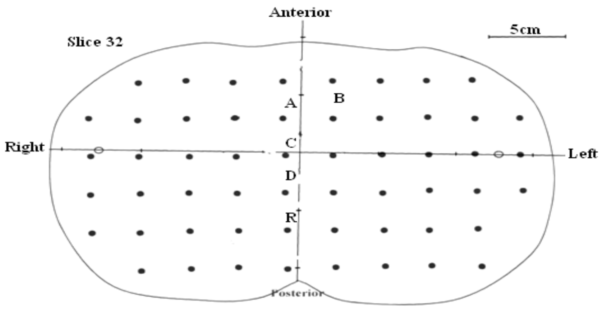

Figure 3. the graphic illustration of the chosen points.

For AP-PA technique, the mean rectal dose was higher than the target volume dose. Table 1 shows the comparison of the mean absorbed dose determined by TLD in all of the techniques following cervix cancer treatment. Technique # 1 indicates two-field, technique # 2 demonstrates three-field, and technique # 3 shows four-field with equal tumor dose and technique # 4 indicates a box with equal applied dose.

The mean absorbed dose by film in rectum and cancer volume among the techniques is shown in table 2. Statistical analysis was also done using Independent Samples *t-test*. Except two field techniques (AP-PA), P-value for all other techniques is lower than 0.05. Analysis of the target volume data showed that there was no significant difference. Statistical analysis in this case was also done using Independent Samples *t-test*. Comparison of all data points' showed p- values less than 0.001.

Table 1. Comparison of the mean absorbed dose by TLD following cervix cancer treatment in different techniques with linear accelerator.

Techniques	Dose				*T-Test*
	Rectum		Cervix		
	Mean	SD	Mean	SD	
Technique # 1	2.079	0.124	2.017	0.048	T = 0.483 P-value = 0.773
Technique # 2	1.526	0.197	1.985	0.036	T = 3.951 P-value = 0.017
Technique # 3	1.418	0.241	1.991	0.099	T = 2.788 P-value = 0.049
Technique # 4	1.671	0.001	1.969	0.016	T = 25.602 P-value < 0.001

Table 2. Comparison of the mean absorbed dose by film following cervix cancer treatment in different techniques with linear accelerator.

Techniques	Dose			
	Rectum		Cervix	
	Mean	SD	Mean	SD
Technique # 1	2.13	0.14	2.00	0.15
Technique # 2	1.79	0.08	2.07	0.05
Technique # 3	1.69	0.05	2.07	0.12
Technique # 4	1.64	0.09	2.07	0.04

The experiments were repeated 3 times and three points were used to read film dose. The comparison of TLD and Gafchromic film dosimetry with treatment planning dose was done by paired *t-test*. The measured dose (with TLD and Film) in all points was significantly same as the calculated dose by treatment planning. P-values calculated for data obtained by linear accelerator are as follows: Two-field; cervix, p = 0.407; rectum, p = 0.687. Three-field; cervix, p = 0.333; rectum, p = 0.133. Box with equal tumor dose; cervix, p = 0.768; rectum, p = 0.639, and box with equal applied dose; cervix, p = 0.081, rectum, p = 0.709. The comparison of obtained results by TLD, film and treatment planning are shown in figures 4 and 5.

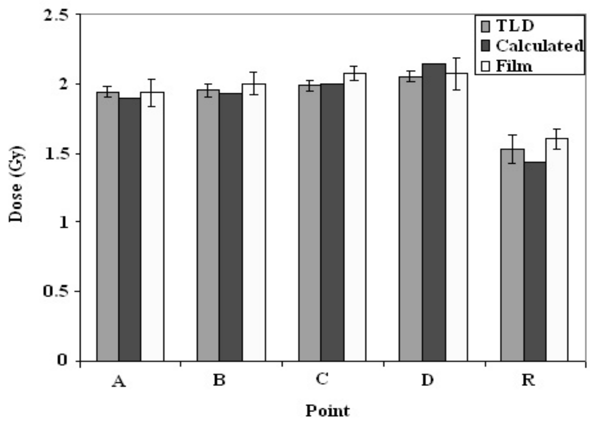

Figure 4. Comparison of the mean absorbed dose by TLD and film with planned dose in three-field technique exposed by 9 MV linear accelerators.

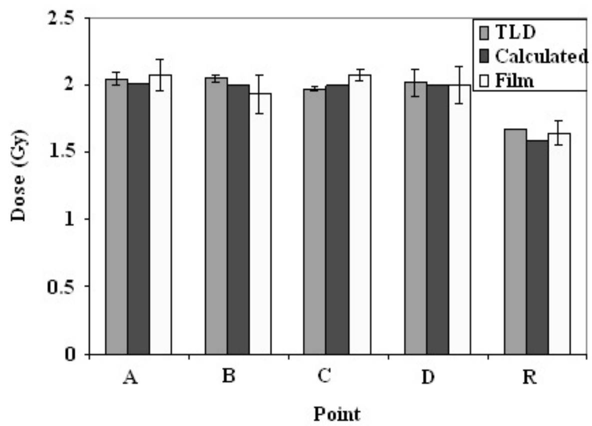

Figure 5. Comparison of the mean absorbed dose by TLD and film with planned dose in four-field technique with equal tumor dose exposed by 9 MV linear accelerators.

DISCUSSION

By using multiple fields, the ratio of the tumor dose to the normal tissue dose was increased. Although multiple fields could provide good distribution, there are some clinical and technical limitations in these methods. For example, certain beam angulations were practically impossible due to the presence of critical organs. Also, the set-up accuracy of a treatment may be better with parallel opposed than with multiple angles beam arrangement [15]. A similar study reported by Hudej *et al.* [16] showed that dosimetry using TLD and film during radiotherapy could have a useful role as a predictor of the best technique for preventing future rectal complications. The use of TLD and Gafchromic film to assure sub-millimeter accuracy for image-guided radiosurgery was done in 2008 by Ho *et al.* [17]. As far as comparison of point measured dose is concerned the following conclusions could be drawn:

- Maximal rectal dose was obtained using two-field technique.
- Considering similar target volume, best normal tissue sparing was obtained by using the three-field technique and four-field technique with equal tumor dose.
- There is a uniform dose distribution throughout the tumor volume.
- In comparison of the TLD and XR type T film dosimetry results with the prescribed dose, it was demonstrated that there was not a statistically significant difference between the measured and prescribed dose by tumor volume and rectum.

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