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Original Article

Applicator Attenuation Effect on Dose Calculations of Esophageal High-Dose Rate Brachytherapy Using EDR2 Film

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Abstract

Introduction
Interaluminal brachytherapy is one of the important methods of esophageal cancer treatment. The effect of applicator attenuation is not considered in dose calculation method released by AAPM-TG43. In this study, the effect of High-Dose Rate (HDR) brachytherapy esophageal applicator on dose distribution was surveyed in HDR brachytherapy.

Materials and Methods
A cylindrical PMMA phantom was built in order to be inserted by various sizes of esophageal applicators. EDR2 films were placed at 33 mm from Ir-192 source and irradiated with 1.5 Gy after planning using treatment planning system for all applicators.

Results
The results of film dosimetry in reference point for 6, 8, 10, and 20 mm applicators were 1.54, 1.53, 1.48, and 1.50 Gy, respectively. The difference between practical and treatment planning system results was 0.023 Gy (<2.7%), on average.

Conclusion
Due to the similar practical results for different esophageal applicators, it can be concluded that attenuation properties of applicator wall doesn't have a significant difference with water and therefore the Flexiplan treatment planning system accuracy is further confirmed.

Keywords: Brachytherapy, Film Dosimetry, PMMA

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1. Introduction

Esophagus cancer is currently one of the most dangerous cancers in the world. In Iran, the spread rate of this cancer is higher than the world mean [1]. Intraluminal High-Dose Rate (HDR) Brachytherapy method is used for the treatment of this disease. In this method, some applicators made of plastic are sent into the body through esophagus and after scanning the patient, the appropriate treatment is designed by a special software. Afterward, the applicator is attached to the brachytherapy device; the source inside the applicator is removed and after entering into the body stops in different locations and the prescribed dose is given to the desired points in accordance with the treatment plan [2-5].

In this method, different applicators with external diameters varrying from 6, 8, 10, 12, 14, 16, and 20 mm are used [3]. Usually the biggest applicator which is tolerable by the patient is used in this treatment. One model of these applicators is shown in Figure (1).

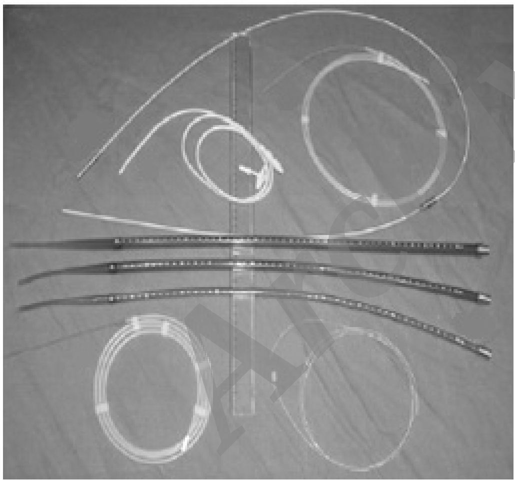

Figure 1. Esophagus HDR brachytherapy applicators [3].

In Iran, Flexitron is the main treatment device used for brachytherapy. The treatment planning system used in this device is Flexiplan treatment planning software which is designed based on AAPM-TG43. In this protocol, all the materials even the applicator side is considered as equivalent to water [6]. Considering the differences between the applicator diameters and the fact that attenuation of the plastic wall of applicators can have considerable effects on the received dose rate in any points should be kept in mind. In planning phase of the treatment, this plastic wall is considered as equivalent to water [7] and if in practice, there is a difference between the effects of the applicator plastic wall attenuation and the soft context or water, the achieved results of the treatment planning will not be in accordance with the practical treatment and causes a decrease in the accuracy and preciseness of the treatment.

Because of the high rate of the absorbed dose in every treatment session and the fact that there aren't many sessions in this brachytherapy treatment compared with teletherapy, the appearance of some errors in these treatment planning systems should be as few as possible.

It is worth mentioning that few researches have been done using investigating the brachytherapy applicators. This research was done in the Flexiplan treatment planning system for the first time in Iran.

Dosimetry and the comparison of breast cancer brachytherapy applicators were done by Yun Yang et al [8]. In the above-mentioned research, Mont Carlo MCNP5 code and the practical dosimetry were used by radio chromic film and Farmer ionization chamber [8].

A research in comparing the applicators of the gamma meter was also carried out by Sanjay Sudhakar Supe et al. In this research the dosage distribution in the treatment plan has been simply compared in the reference point for the applicators of 8, 10, 12, and 14 mm [9].

This research aims at investigating the effects of the applicator wall attenuation and comparing it with the effects of the soft context attenuation as well as evaluating the amount of the effect of the applicator side attenuation in the uncertainty of the carried out treatment planning in esophagus HDR brachytherapy.

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2. Materials and Methods

2.1. Phantom

A neck-like cylindrical phantom whose mass is equivalent to water should be used for the investigating the effects of the applicator side attenuation. After some investigations, the phantom was chosen to be made of Poly methyl methacrylate (PMMA). The PMMA mass absorption coefficient is in accordance with the water mass absorption coefficient (Figure 2) [10]. This phantom was made of a 10-cm diameter cylinder with height of 15 cm.

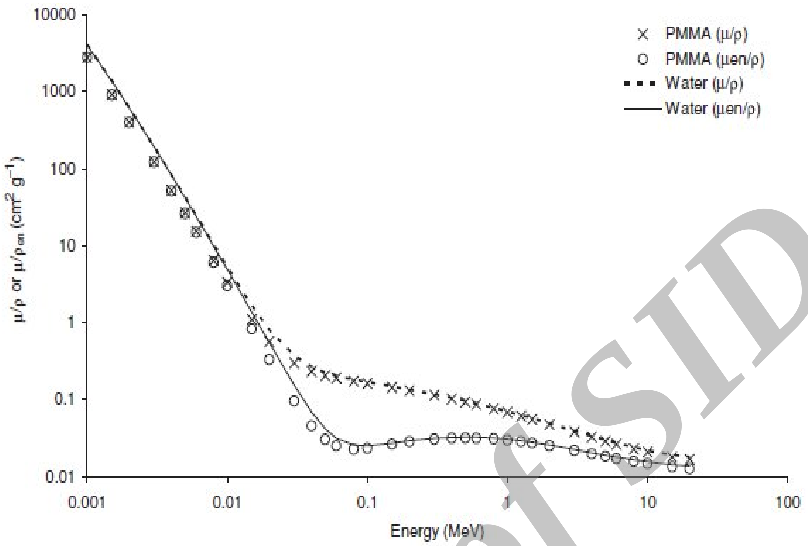

Figure 2. Comparing the mass absorption coefficients of PMMA and water [10].

For the placement of the desired applicator inside the phantom, a 20 mm diameter hole was created in its center. In order to perform dosimetry, a 33-mm scratch was created far from the cylinder center along the cylinder length which is the location point for the film. Figure 3 shows this phantom.

Figure 3. A photo illustrating the phantom in the current study

For the placement of the applicators inside the phantom, cylinders made of PMMA with the external diameter of 20 mm were used. These cylinders had a tube equivalent to the external diameters of the applicators. These cylinders are illustrated in Figure 4. The central hole along with the small cylinder inside it is similar to esophagus anatomy while placing the applicator into the body.

Figure 4. PMMA cylinders with 20 mm diameter

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The sum of each applicator diameter and its corresponding cylinder is equivalent to 20 mm. for example, in the case of having a 6 mm applicator, the PMMA will be 14 mm and for a 16-mm applicator the PMMA applicator side will be 4 mm. As mentioned before, in Flexiplan treatment planning software, all materials are considered to be equivalent to water. Therefore, it can be expected that if each one of these applicators and their corresponding cylinders are placed into the phantom and the same treatment plan are carried out in the same point of the phantom, the achieved results of the treatment design will be completely similar, using the applicators with different diameters. Because in all cases the software will consider a 20-mm cylinder made of water in its calculations. However, when this experiment is carried out in practice, and the effects of the applicator wall attenuation is different from PMMA (which is equivalent to soft context of water), the achieved results of the dosimetry will vary depending on the applicator diameters.
Related to this point and using the applicators with diameters of 6, 8, 10, and 20 mm, the difference between the effects of applicator wall attenuation and the soft context was finally investigated after dosimetry in some certain points inside the phantom.

2.2. EDR2 film and calibration

In the current study, Extended Dose Range (EDR2) was used for the practical dosimetry. Radiographic films were used and because of their sensitivity to light they were covered with a black wrap. The film thickness along with the cover is about 1 mm which has been considered while making the phantom. The response of this kind of film is dependent on the energy and this response is linear between 0.5 to 2 Gy in the case that the corresponding energy of 192 irridium radiation (the source used in this research) is considered and this fact can be observed in the calibration curve of the used films (Figure 5).

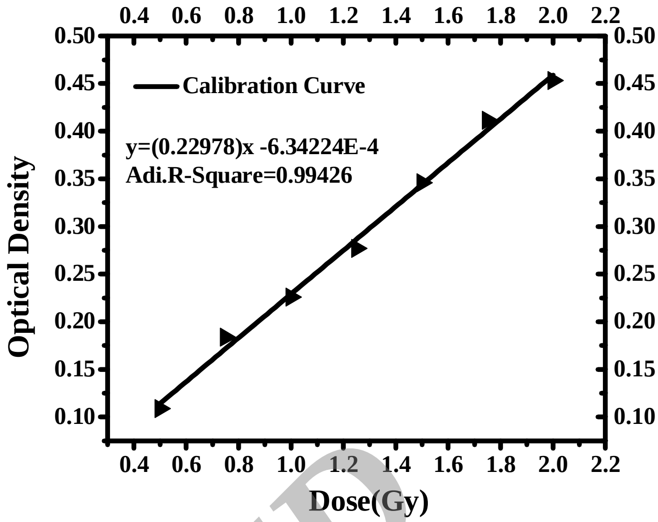

Figure 5. Calibration curve of EDR2 film.

The dimensions of the used films in the process of calibration are 4×15 cm and the films are calibrated by the special (standard) 192 iridium source. For doing this, the standard source is placed inside the water phantom in a particular distance from EDR2 film. Afterward, using the calculation by TG43 protocol for loading the desired dose rate on the film, the pause time of the source in this point can be calculated and this process is finally carried out. In this case, after developing each film and calculating their optical density and attributing it to the loaded dose, the calibration curve is drawn.

2.3. Measurement in the phantom

In this phase, all of the applicators and their corresponding cylinder and the marker wire were placed inside the phantom and then sent to the CT scan unit. (The marker wire is a strip with small pieces of lead that are placed 1 cm far from each other and make it easier to find the location of the source in the phase of the treatment planning (Figure 6)).
After scanning, phantom information for each applicator was imported to the Flexiplan treatment planning system. A similar treatment plan was carried out for all the applicators so that 1.5 G dose could be loaded in 33 mm far from the source in the film center in this treatment plan. The corresponding treatment

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plan for the 20 mm applicator is illustrated in Figure 7.

Figure 6. The procedure for the phantom CT scanning.

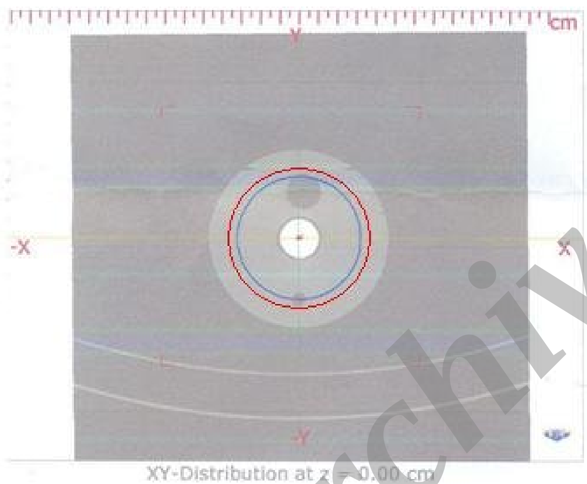

Figure 7. The designed treatment plan for 20 mm applicator. The red curve illustrates the 1.5 isodose Gy in the center of the film. The central white circle shows the applicator image in CT scan process.

After treatment planning, the radiographic film used for this project was placed in the desired point inside the phantom and the applicator was connected to Flexitron Brachytherapy system. A 192 iridium source whose activity is more than 2 curies is used in this system (The gamma spectrum obtained from this radio isotope is between 0.06149 and 0.88454 MeV with the 0.38 average MeV [5]).

Afterward, the source enters the phantom through the applicator and stops in different locations and the prescribed dose rate is given to the desired points in accordance with the treatment plan.

In order to read the film after radiation, the film was developed in a dark room and placed into the film processor device for 3 minutes. Then, the processed film was scanned by microtech scanner (Maker 9800 XL Scanner) and the film darkness was read by ImageJ version 1.1 software. These values are transformed to the optic density by:

$$O.D = Log\frac{I_0}{I}$$

Where I_0=65280 is the film darkness of scanning without the film. The films cannot be scanned before radiation (because of sensitivity to light). In order to obtain the fog and base of the films, a film without radiation is used which has been maintained in the same condition as other films and then it is developed. The net darkness of each film is obtained by scanning this film and calculating the fog and base rate which is very insignificant, and by subtracting from calculated film darkness using the above formula for each of the films.

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2.4. Data Analysis

The significance level of the difference between results of the dosimetry with different applicators was analyzed using SPSS version 17 and the variance analysis test (t-test) was used to analyze the significance of the dosimetry results.

3. Results

The results obtained from the practical dosimetry with the film corresponding to different applicators are shown in Table 1 respecting three measurements for each applicator.

The Image software was used for the film analysis and the film darkness was measured in the given point in the film. Afterward, the optical density was computed and the dose rate delivered to each film was calculated with respect to calibration curve as shown in Figure 6.

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The results of the statistical analysis show that there was no meaningful difference between the doses measured using the applicators with different diameters (p>0.10).

Table 1. The results of the practical dosimetry.

Applicator diameter (mm)	Loaded dose in plan (Gy)	First dosimetry (Gy)	Second dosimetry (Gy)	Third dosimetry (Gy)	Mean of practical dosimetry (Gy)	Standard deviation	Relative error
6	1.5	1.52	1.55	1.55	1.54	0.015	2.7%
8	1.5	1.53	1.53	1.53	1.53	0.001	2.1%
10	1.5	1.49	1.48	1.49	1.49	0.004	1%
20	1.5	1.50	1.49	1.51	1.50	0.007	0%

4. Discussion and Conclusion

According to Table 1, the maximum difference between the doses measured by the film while placing different applicators is 3%.

Emphasizing on the software results, it can be said that there is no significant difference between the obtained results using different applicators. The small difference between the results only depends on the systematic errors of the measurement tools or statistical errors of the carried out measurements. Therefore, it can be said that the attenuation effects of the applicator wall used in esophagus brachytherapy is similar to water in 192 iridium source energy and the fact that these walls are considered to be equivalent to water in the treatment planning of esophagus brachytherapy performed by Flexiplan software won't have any negative effects on the accuracy of the above-mentioned treatment plan.

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