Volume 12, No 4 | International Journal of Radiation Research, October 2014

Dose measurement outside of radiotherapy treatment field (Peripheral dose) using thermoluminesent dosimeters

N. Banaee[1], H.A.Nedaie[2*], E. Esmati[2], H. Nosrati[3], M. Jamali[2]

[1]Department of Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2]Radiotherapy Oncology Department, Cancer research Centre, Tehran University of Medical Sciences, Tehran, Iran
[3]Shahid Beheshti University of Medical Sciences, Tehran, Iran

▶ ***Original article***

Corresponding author:
Dr. Hassan Ali Nedaie,
***Fax:** +98 21 66948673*
E-mail:
Nedaieha@sina.tums.ac.ir

Revised: Dec. 2013
Accepted: March 2014

Int. J. Radiat. Res., October 2014; 12(4): 355-359

ABSTRACT

Background: In radiation therapy, peripheral dose or the dose outside the radiotherapy field, is important when anatomical structures with very low dose tolerances are involved. One of these critical organs in pelvic irradiation is testis. The amount of radiation delivered to the testes in radiotherapy must be kept as small as possible, consistent with the limit dose of this organ. The threshold doses for temporary and permanent sterility are 0.15 Gy and 6-8 Gy, respectively. Therefore, in pelvic irradiation, protecting testis from these doses and also scattered radiation which could escalate testis dose should be considered. ***Materials and Methods:*** In order to determine the possibility of using testicular shield for high and low energies, TLD dosimetry was done on phantom and 27 patients involved with bladder, rectum and prostate cancers. ***Results:*** Dosimetric results showed that the ability of testicular shield in reducing testes absorbed dose is approximately the same (about 7 cGy) for low and high energy photon beams. ***Conclusion:*** a testicular shield with a fixed thickness of 1.27cm can be used as testis protection for either high and low energies.

Keywords: *Testicular shield, pelvic irradiation, peripheral dose.*

INTRODUCTION

Radiotherapy is one of the treatment modalities for pelvic tumors which are located in bladder, rectum and prostate (1). In these cases, there are many critical organs near the irradiated volume which may receive dose because of photon scattering from treatment field. Photon scattering may be caused by treatment head leakage, secondary collimator and patient scattering. The dose that is delivered to organs outside the treatment volume, is called peripheral dose (2). Testis is one of the critical organs in pelvic cancers that despite of locating outside of radiotherapy field, may get high dose level of scattered radiations. According to one of the latest research, a dose of 0.1 Gy causes temporary reduction in the number of spermatozoa, a dose of 0.15 Gy makes temporary sterility and doses between 6 to 8 Gy lead to permanent azoospermia (3).

Unfortunately nowadays a significant number of men are involved with cancers of prostate, bladder and rectum. For these patients especially for youngers who wish to father children the risk of infertility is of concern (4). The importance of this issue will allow using devices for reducing the absorbed dose to testes. The aim of this study is to evaluate the amount of radiation absorbed by testes in pelvic irradiations and analysing the necessity of using testicular shield for protecting testes.

MATERIALS AND METHODS

This study consists of two parts: first, dosimetry on phantom at energies of 6 and 18MV. Second, dosimetry on patients treated by 18MV photon beams.

GR-207A thermoluminescent dosimeters (TLD) manufactured by Fimel company, were used to measure doses of especial points. TLDs need to be calibrated before using. TLD calibration should be done in two processes which are determining Element Correction Coefficients (ECC) and plotting calibration curve [5]. In order to acquire ECCs, each TLD was positioned in specialized holes on a perspex slab at the depth of maximum dose at 6MV photon beam produced by a Varian linear accelerator. A dose of 100 cGy was irradiated to TLDs to acquire the element correction coefficient (ECC). The element correction coefficient was calculated from equation 1.

$$ECC_j = \frac{\langle TLD \rangle}{TLD_j} \qquad (1)$$

Where <TLD> and TLD j are average of reading of the total TLDs and individual reading, respectively.

The effective energy used in this study was the energy of scattered photons from 6 and 18 MV photon beams with mean energy of 500 KeV [6]. Because of limitations to produce this range of energy, the energy of 200 kVp from orthovoltage therapy beams was selected for calibration of TLDs. Calibration process included 8 dose steps consist of 0, 5, 10, 20, 30, 50, 80, 100 cGy. Adequate slabs were used to prepare electron equilibrium conditions. TLDs were read out by TLD reader (Fimel, Velizy, France) and calibration curve (count versus absorbed dose) was plotted. Figure 1 illustrates calibration curve of TLDs.

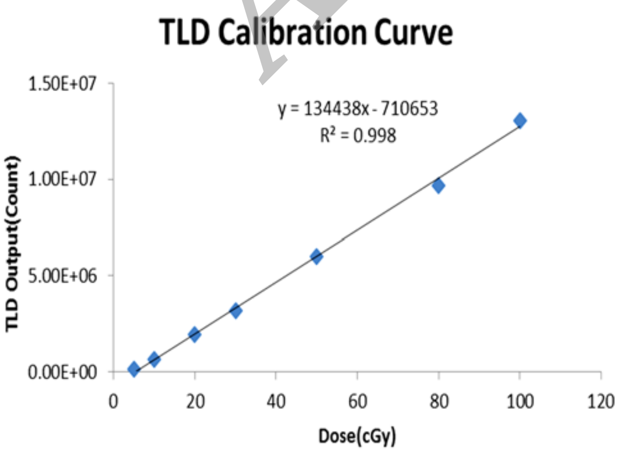

Figure1. TLD calibration curve.

At onset of the study, dosimetry was done on Perspex (PMMA) slabs at three fixed points outside the radiotherapy field at 6 and 18 MV photon beams in a 10×10 cm^2 field. Then a medium standard testicular shield manufactured by Radon company, (Radon, Ankara, Turkey), with properties such as 1.2" (1.27 cm) lead wall thickness, ID 2 ½", OD 3 ½" and 5.7 lbs, was used to determine the possibility of using this shield for investigated energies. Dosimetry was done at surface of the shield (point A), inside the shield (point B) and without using shield (point C). Figure 2 shows the schematic positions of points A and B.

Points A and C had the same geometrical and physical conditions, 4cm below the lower edge of the field (at 9 cm from centre of the field).

At second step, in vivo dosimetry was performed. 27 patients with bladder, prostate and rectal cancers took part in this study. The demographic characteristics of the patients are tabulated in table1 .All patients were treated by linear accelerator in supine position with 18 MV photon beams and different field sizes and various distances of testes to lower edge of the treatment field and disparate numbers of treating field. Some patients were treated with three fields, some with four and the others with five fields. The absorbed dose of testes was the dose delivered by all treating fields (including

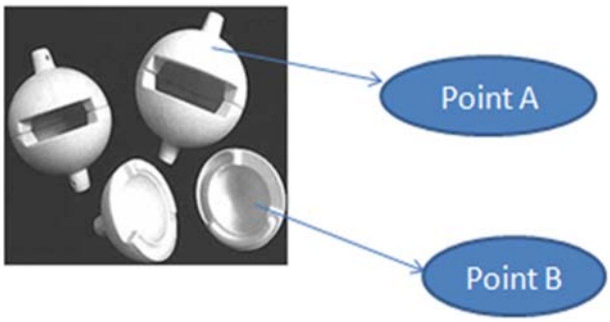

Figure 2. Schematic position of points A and B.

AP, PA, Right Lat, Left Lat and Obliques). In order to have equal situation of physical points for dosimetry, for all patients dosimetry was done 5 cm below the illac crest. A dose of 50 Gy was delivered to patients in 25 fractions (2Gy per fraction). Dosimetric processes were done in two sessions, one by using testicular shield (at surface of the shield and inside it, points A and B, respectively) and the other without using testicular shield (point C). In order to have high accuracy of dosimetric results for each point, three TLDs were used and the absorbed dose was the average dose obtained by three TLDs.

RESULTS

The absolute dose of special points (A, B and C) on phantom at energies of 6 and 18 MV was measured by TLDs. Table 2 illustrates the dosimetric results on phantom. The dose at each point is the average of the dose obtained by 3 TLDs.

Similarly, the absolute dose absorbed by testes for 27 patients with pelvic cancers who participated in this study was measured by TLDs. For these 27 patients all treatment processes were the same (treated by 18 MV photons, supine position and 2 Gy per fraction) and varying only field sizes and distance from lower edge of the field and numbers of treating fields. Table 3 represents the dosimetric results of 27 patients.

DISCUSSION

As mentioned, scattered radiation to the testis has many harmful effects. These effects include oligospermia, temporary azospermia [7],

Table 1. The demographic characteristics of the studied patients.

NUMBER OF PATIENTS	DIAGNOSIS	FIELD SIZE (cm^2)	DISTANCE FROM LOWER EDGE OF THE FIELD	AGE
1	Prostate	10×4.8, 10.2×5.1	4cm	62
2	Prostate	8×7	4.7cm	69
3	Prostate	7.6×8.6, 8.6×6.2	6.2cm	58
4	Prostate	7×7, 6×7.5	6.5cm	72
5	Bladder	15×17	9.5cm	75
6	Bladder	12×7.6	7.5cm	73
7	Prostate	11×11.5, 13×7.5	6cm	59
8	Prostate	9.5×9, 9.5×6	5.2cm	65
9	Prostate	6.6×6.6, 7×6.5	7cm	66
10	Prostate	11×10.6, 11×8	6cm	82
11	Prostate	6×7, 7×6	4.5cm	60
12	Prostate	8×8, 7×8	5.5cm	74
13	Prostate	15.5×17, 12.5×17	2.5cm	84
14	Rectum	15×20.6, 11×20.6	4cm	89
15	Prostate	14×15, 11×15	4cm	60
16	Prostate	14.5×16, 11×16	3.5cm	58
17	Prostate	14×17, 13×17	3.5cm	66
18	Rectum	15×22, 13×22	2.5cm	59
19	Rectum	15×17.5, 11.5×17.5	2cm	71
20	Prostate	16.5×21, 12×21	3.5cm	49
21	Prostate	15×17, 17×12	2cm	80
22	Bladder	13×12, 12×10	8cm	86
23	Prostate	10.5×9.0, 8×9	7cm	78
24	Bladder	15×20, 24×14	19cm	84
25	Prostate	10×6, 8×6	5.5cm	59
26	Prostate	10×16, 8×16	6cm	60
27	Prostate	10×12, 6×12	5cm	64

and permanent azospermia, changes in the hormonal (LH-FSH) levels [8], testicular atrophy [9] and genetic risk of hereditary disease or developmental impair-ment for the offspring of irradiated patients [10]. These effects clarify the advisability of using testicular shield in pelvic irradiations.

Comparing the dosimetric results (tables 2 and 3) on patients and phantom, it can be seen that testicular shield has an important role in decreasing absorbed dose received by testes. Table 2 shows that a fixed thickness (1.27 cm) can be used for high and low energy irradiations. In other words, the ability and efficiency of testicular shield in reducing the dose of outside of radiotherapy field for two investigated energies is approximately the same.

The energy of scattered photons from 6 and 18 MV photon beams is about 500 KeV [5, 6]. Regarding to the equality of scattered photon energies of 6 and 18 MV photon beams, it does not make sense to use various thickness of shields at different energies.

Two important factors, field size and distance from lower edge of the field, have influence on amount of absorbed dose. By increasing field size, photon scattering growths and therefore peripheral dose increases and distance from lower edge of the field has inverse correlation with peripheral dose.

By using testicular shield, a reduction of 40% -70% can be seen on absorbed dose of

Table 2. Dosimetric results on phantom.

ENERGY	FIELD SIZE (cm^2)	DISTANCE FROM LOWER EDGE OF THE FIELD	DOSE OF POINT A (cGy)	DOSE OF POINT B (cGy)	DOSE OF POINT C (cGy)
6MV	10×10	4cm	18.9 ± 0.1	7.3 ± 0.1	16.7 ± 0.1
18MV	10×10	4cm	25.6 ± 0.2	7.5 ± 0.5	22.3 ± 0.5

Table 3. Dosimetric results of patients treated by 18 MV photon beams.

PATIENT NUMBER	DOSE OF POINT A (cGy)	DOSE OF POINT B (cGy)	DOSE OF POINT C (cGy)
1	16.74±0.38	7.10±0.05	15.57±0.01
2	14.48±1.51	7.73±0.27	13.83±0.21
3	11.35±0.54	7.14±0.29	9.36±0.04
4	10.79±0.16	6.48±0.02	9.62±0.12
5	15.28±0.26	6.87±0.08	14.44±0.03
6	15.02±0.33	7.29±0.06	14.04±0.55
7	20.11±0.32	7.65±0.17	18.34±0.02
8	15.81±0.63	6.78±0.02	14.82±0.01
9	10.28±0.98	6.57±0.04	9.68±0.01
10	10.51±0.37	6.35±0.03	10.14±0.05
11	11.70±0.35	6.70±0.17	10.82±0.07
12	12.01±1.16	6.62±0.10	11.56±0.08
13	29.01±0.37	9.93±0.31	26.29±0.07
14	17.62±0.74	7.97±0.07	15.05±0.09
15	20.76±0.86	7.77±0.07	18.04±0.08
16	21.30±0.10	8.26±0.52	18.32±0.19
17	23.81±0.15	8.77±0.08	19.41±0.27
18	35.97±0.25	10.06±0.04	32.40±0.03
19	30.25±0.39	9.70±0.08	28.09±0.72
20	19.85±0.05	7.73±0.13	7.70±0.35
21	20.31±0.94	7.95±0.03	18.24±0.02
22	15.58±0.20	7.06±0.12	14.60±0.10
23	11.59±0.16	6.62±0.11	6.46±0.05
24	13.05±0.16	5.84±0.01	5.71±0.02
25	15.06±0.12	6.23±0.12	13.89±0.03
26	22.84±0.15	8.02±0.17	20.05±0.04
27	11.98±0.15	6.9±0.73	10.23±0.43

testes. As this reduction shifts absorbed dose to values under the threshold doses for permanent sterility (6-8 Gy), it helps for the perpetuity of the accurate function of testes. Moreover, by using testicular shield, the dose increases at surface of the shield (comparing dosimetric results at points A and C). This matter is because of back scatter radiations that are produced at surface of the shield but as there was not any critical organ at the surface of the shield, this dose increasing does not affect on application of the shield.

Peripheral dose becomes more important in higher energies. Regarding to values of absorbed dose at 6 and 18 MV, it can be seen that by increasing energy, peripheral dose increases at a fixed point outside the radiotherapy field. It is not consistent with Budgell *et al.* who measured the scattered photons dose delivered to testes at 4, 8 and 20 MV. They concluded that peripheral dose decreases by increasing energy (4).

CONCLUSION

Testicular shield is a suitable device for reducing peripheral dose of testes in treatments done by low and high energies. It provides sufficient protection for testes and makes a 40-70% reduction in testes absorbed dose of patients treated by 18 MV photon beams. By increasing energy, peripheral dose grows and therefore it becomes more important in higher energies. Equality of the mean energy of scattered photons from 6 and 18 MV photon beams leads to use a single testicular shield with a fixed thickness of 1.27 cm for both energies.

Conflict of interest: *Declared none.*

REFERENCES

1. Nazmy MS, El-Taher MM, Attalla EM, El-Hosiny HA, Lotayef MM (2007) Shielding for Scattered Radiation to the Testis During Pelvic Radiotherapy: Is it worth?. Journal of the Egyptian Nat. *Cancer Inst, **19** :127-132.*
2. Sharma DS, Animesh, Deshpande SS, Phurailatpam RD, Deshpande DD, Shrivastava SK, Dinshaw KA (2006) Peripheral dose from uniform dynamic multileaf collimation fields: implications for sliding window intensity-modulated radiotherapy. *British Journal of Radiology, **79:** 331–335*
3. hall JE and Amato J (2006) Radiobiology for the radiobiologist. LIPPINCOTT WILLIAMS & WILKINS Co, USA.
4. Budgell GJ, Cowan RA, Hounsell AR (2001) Prediction of scattered dose to the testes in abdominopelvic radiotherapy. *Clinical Oncology, **13:**120 125.*
5. Shirazi A, Mahdavi SR, Khodadadee A, Gaffory M, Mesbahi A (2008) Monte Carlo simulation of TLD response function: Scattered radiation field application. *Rep Pract Oncol Radiother, **13(1):** 23-28*
6. Kase RK and Svensson GK (1986) Head scatter data for several linear accelerators (4–18 MV). *Medical physics, **13:**530-532.*
7. Jacobsen KD, Olsen DR, Fosa K, Fossa SD (1997) External beam abdominal radiotherapy in patients with seminoma stage I: field type, testicular dose and spermatogenesis. *Int J Radiat Oncol Biol Phys, **38:** 83-94.*
8. Boehmer D, Badakhshi H, Kuschke W, Bohsung J, Budach V (2005) Testicular dose in prostate cancer radio-therapy: Impact on impairment of fertility and hormonal function. *Strahlenther Onkol, **181**: 179-84.*
9. Daniell HW and Tam EW (1998) Testicular atrophy in therapeutic orchiectomy specimens from men with prostate carcinoma. *Cancer, **83:** 1174-9.*
10. Herrmann T, Thiede G, Trott KR, Voigtmann L (2004) Off-springs of preconceptionally irradiated parents. *Strahlenther Onkol, **180:** 21-30.*