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Full Length Article

Scattered radiation to gonads: Role of testicular shielding for para-aortic and homolateral illiac nodal radiotherapy

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KEYWORDS

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Abstract *Background:* Scattered radiation to organs at risk deserves great attention during radiotherapy especially when the concern is about fertility. Minimizing the delivery of scattered radiation to the gonads while treating abdominal nodes or pelvic fields in male patients requires adequate shielding of the testes to preserve testicular functions. We constructed a testicular shield with cerrobend for the purpose of treatment of seminoma of testis stage I and IIA disease.

Materials & methods: An outer shell of coconut of required dimensions was taken as a base over which cerrobend was poured to obtain two semi-spherical half testicular shields. Five patients of seminoma early stage (stage I and IIA) were treated with this testicular shield.

Results: The estimated total dose received by the testis by scatter radiation after completion of the treatment was 0.115 Gy (0.28%) of total mid-plane dose of 40 Gy delivered by inverted Y field. At a distance of 8 cm from the inferior field border the 2 cm thick cerrobend testicular shield provided a shielding factor of 3.2/0.3 = 10.33.

Conclusions: With proper testicular shielding, doses as low as 0.28% of the prescribed dose can be achieved. This low dose is believed to maintain the fertility of the patient.

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Introduction

Scattered radiation to organs at risk deserves great attention during radiotherapy especially when the concern is about fertility. The main source of scattered radiation is the leakage from collimator and internal scatter within the body of the patient [1]. In the developing countries, teletherapy with cobalt^{60} machine is still the primary mode of radiotherapy. The main problem with the cobalt machine is the low beam energy which leads to higher peripheral doses, doses as high as 20% of the

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Table 1 Measured dose in phantom expressed as % of the mid plane dose delivered to the patient.

Distance from field inferior border in cm	Percentage of dose without shielding	Percentage of dose in lower half shield alone	Percentage of dose in lower + upper half of shielding together
3.5	6.5	3.8	0.9
8.0	3.2	1.3	0.3

central axis dose is delivered at a distance of 2 cm from beam edge of cobalt machine [2]. Maintenance of reproductive function is one of the most asked questions to a radiation oncologist when treating a patient of the young age group. Minimizing the delivery of scattered radiation to the gonads while treating abdominal nodes or pelvic fields in male patients requires adequate shielding of the testes to preserve testicular functions. Chao et al. reported that doses of more than 50 cGy to the gonads and cumulative dose of more than 200 cGy may lead to permanent sterility [1]. This necessitates the adequate shielding of the testis to less than 2% of the recommended dose. Purdy et al. used a secondary gonadal shield made up of cerrobend for use in the pelvic irradiation of males was designed and found that the gonadal dose was reduced to approximately 1.5–2.5% of the given dose [4]. Fraass et al. described the use of specially made testicular shield device to achieve less than 1.5% mean prescribed dose [5]. Bieri et al. evaluated the influence of different shielding conditions and field geometry on the scatter dose to the remaining testicle during postoperative radiotherapy in seminoma and reported significant reduction in the dose [6]. We constructed a testicular shield with cerrobend for the purpose of treatment of seminoma of testis Stage I and IIA disease.

Material and method

An outer shell of a coconut of required dimensions was taken as a base over which cerrobend was poured to obtain two semispherical half testicular shields. Cerrobend was chosen as it is light weight and has a low melting point. After drying the prepared shield had an outer diameter of 8 cm and inner diameter of 6 cm. At one of the shields, a V shaped cut was made on the top portion for the insertion of scrotum. Inner surface was further smoothened by the use of dental wax coating. This was done to minimize backscatter of electrons from the shield. The abdominal part of standard humanoid phantom (Male Alderson Rando phantom, Imaging solutions, Australia) was irradiated simulating the patient's treatment conditions to measure the dose delivered by inverted Y field. Farmer ionization chamber (0.6 cc) with a build up cap was used to measure the scatter radiation inside the testicular shield.

Table 3 Energy of the scatter reaching the point proximal to the radiation field.

Long axis of primary field in cm	Scatter photon energy for 1.25 MeV (Co60) mean at 6 cm (keV)
22	789
35	673

Five patients with median age of 32 years were treated for early stage (Stage I and IIA) seminoma testis with therateron 780E and 780C cobalt^{60} teletherapy machine with testicular shield in place. 40 Gy dose was prescribed in 20 fractions delivering 2 Gy per fraction and 5 fractions per week. The testicular shield was supported by a rectangular sponge placed between the thighs. A modified dog-leg field was used to encompass the nodal regions at risk. The superior border was placed at the junction of T10-T11 vertebra and the lower border at the level superior aspect of the acetabulum.

Polythene bag was used to place the uninvolved testis inside the shield. The dose delivered to testis despite shielding measured with the help of precalibrated CaSo4:Dy thermo luminescent disc (TLD) of size 9 mm × 13 mm was placed on scrotal surface. The scattered dose received by TLD was measured by NUCLEONIX TL 10091 TLD reader. After one set of measurement, the discs were annealed by heating up to 400 °C and then used for next measurements carried out at 1st week, 2nd week, and 3rd week. The readings of the TLD were compared with those obtained from the detectors exposed to a known and fixed dose in the tissue equivalent phantom at the depth of 5 cm to calculate the absorbed dose in cGy.

The energy of scattered photon was calculated utilizing the standard formula for Compton scattering (Eq. (1)). The energy of the incident beam (hv) was taken as 1.25 MeV.

$$E = hv\left[1\Big/\left\{1+\left(\left(\frac{hv}{m_0c^2}\right)(1-cos\alpha)\right)\right\}\right] \quad (1)$$

Results

Table 1 depicts the doses as measured by the ionization chamber in the phantom in the absence of testicular shield; the doses were 6.5% and 3.2% of the mid-plane dose at the central axis at a distance of 3.5 and 8 cm from the proximal edge of the field respectively. When the shield was used in lower half, these doses reduced to 3.8% and 1.3%, respectively, while when both upper and lower half shields were placed in position, the corresponding doses were 1.2% and 0.6%. The mean AP doses in the 5 patients were 0.563 CGy (±0.123) while the mean PA dose was

Table 2 Measured testis dose by TLD during treatment on different days.

Patient number	1		2		3		4		5	
Field	AP	PA	AP	PA	AP	PA	AP	PA	AP	PA
Measurement no. 1	0.43	0.53	0.54	0.63	0.87	0.90	0.65	0.56	0.67	0.76
Measurement no. 2	0.56	0.58	0.49	0.47	0.57	0.49	0.37	0.57	0.56	0.49
Measurement no. 3	0.48	0.46	0.63	0.64	0.67	0.54	0.47	0.58	0.48	0.58
Mean	0.49	0.52	0.55	0.58	0.70	0.64	0.49	0.57	0.57	0.61
Standard deviation	0.065	0.060	.070	0.095	0.152	0.223	0.141	.010	0.095	0.137

Table 4 Scattered radiation doses at the testis from different previous studies.

No.	Report taken from	Energy of photon beam	Percentage of testicular dose without shielding	AP field with shield	Percentage of testicular dose without shielding	PA field with shield
1	Bieri et al.	18 MV	1.95%	0.74%	0.93%	0.33%
2	Fraass et al.	10 MV	2.00%	0.40%	2.5%	0.5%
3	Purdy et al.	–	4–6%	1.5–2.5%	–	–

0.585 CGy (±0.116). Table 2 shows the measured testicular dose by TLD during treatment in three different days. The estimated total dose received by the testis by scatter radiation after completion of the treatment was 0.115 Gy (0.28%) of total mid-plane dose of 40 Gy delivered by inverted Y field. The energy of scattered photon at 6 cm measured by the standard formula of Compton scattering for 1.25 MeV energy beam is shown in Table 3. For a field of 22 cm, a 1.25 MeV photon beam gave a scattered energy of 789 kev at 6 cm from the gonads (Table 4).

Discussion

Fertility sparing radiotherapy is a challenge to the radiation oncologist while treating the pelvic fields in young male patients. As testes are highly radiosensitive, doses as low as 200 cGy can cause permanent infertility causing significant impairment in the quality of life of these patients due to psychosocial dysfunction. We used 2 cm thick testicular shield made of cerrobend to effectively shield the gonads to receive only 0.28% of the prescribed dose of 40 Gy. This is well below the required limit of 2% of the prescribed dose. Ravichandran et al. used a similar shield of 1.5 cm thickness to treat a patient of seminoma with 15 MeV X-ray beams and found that a scattered dose of 0.8% of prescribed dose of 40 Gy was to be delivered to the uninvolved shielded testis [7]. At a distance of 8 cm from the inferior field border the 2 cm thick cerrobend testicular shield provided a shielding factor of $3.2/0.3 = 10.33$. The upper limit of the testicular shield is believed to reduce the scatter radiation arising from the collimator of the cobalt machine while the lower half shields the internal scattering dose arising from the irradiated volume in the abdomen.

In our study as derived by phantom dosimetry, we found that percentage of dose delivered with only lower half shield in position was 1.3% as against 3.2% in unshielded condition when both upper and lower shields were placed only 0.6% dose was delivered. Murthy et al. studied the effect of field size, penumbra trimmers and back scatter medium [3]. Purdy et al. reported that shielding only at the level of collimator is not sufficient to decrease the radiation dose to the gonads. Thus, additional shielding directly around the testis is recommended [4]. The gonad shield used in our study is different from that used in the previous literature. First, the shape of the shield used is spherical as against box-shaped in earlier reports. The spherical shape of the shield not only shields the testis from scattered photons coming from all the direction, but it is also much lighter. Besides the spherical shape, the composition of the shield in our care is cerrobend, a low melting point and lighter alloy making it suitable for daily clinical use. Fraass et al. reported the relation between the measured dose and depth of measurement within the shield to be insignificant. Also, they reported that only low energy photons are exposed at the level of the gonads [5]. In their study, for patients treated with para-aortic and homolateral iliac fields, the mean testicular doses per fraction were 3.89 cGy (S.D. ± 1.44) and 1.48 cGy (S.D. ± 0.51) without and with gonadal shielding, respectively (P-value <0.001); the corresponding values for exclusive para-aortic fields were 1.86 cGy (S.D. ± 0.86) and 0.65 cGy (S.D. ± 0.35). [5] Similarly, we found that in patients treated with para-aortic and homolateral iliac nodal radiotherapy, the mean testicular dose after shielding was only 0.572 cGy. Thus, a testicular shield of 2 cm thickness is clearly adequate for the required purpose.

Conclusions

With proper testicular shielding, doses as low as 0.28% of the prescribed dose can be achieved. This low dose is believed to maintain the fertility of the patient.

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Conflict of interest

The authors declare no conflict of interest.

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