

Comparison of multileaf collimator and customized blocks for 3-D conformal radiotherapy of prostate cancer with six-field technique

BAHAR BALTARLI¹, VILDAN ALPAN², SAIT OKKAN³, SEDAT KOCA³

¹Pamukkale University Faculty of Medicine, Department of Radiation Oncology, Denizli, ²Vehbi Koç Foundation, Italian Hospital, Department of Radiation Oncology, Istanbul, ³Istanbul University, Cerrahpaşa Medical School, Department of Radiation Oncology, Istanbul-Turkey

ABSTRACT

The recent technological advances in radiation oncology gave us the opportunity to increase the doses given to the tumor tissues while reducing the doses of normal tissues. The shaping of the conformal fields may be achieved by using lead customized (C) blocks, multileaf collimators (MLC) or intensity modulated beams. In this study, in order to minimize the doses of normal tissues, we compared the different conformal treatment techniques and shapes for the radiotherapy in the case of prostate cancer. Dose volume histograms of the six patients' treatment plans generated with multileaf collimation technique and the customized blocks are presented. Six patients with localized prostatic carcinoma who have been treated with conformal irradiation between January 2001 and September 2002 were evaluated retrospectively. They were all chosen to assess the differences between customized blocks and MLC configuration in the definitive radiation therapy of prostate cancer with six-field technique. A total dose of 68.4 -72 Gy to the prostate and seminal vesicles were given to all of the patients with a fractionation of 1.8 Gy/daily. The dose calculation and dose volume histograms were used to compare the resulting dose distributions. The dose was calculated using the pencil beam algorithm in the Theraplan plus treatment planning system. The dose volume histograms for blocks and multileaf collimation technique were compared in terms of normal tissue volume for rectum, bladder and femoral heads and

it was assumed that, although there were small discrepancies between the plans and all of the doses were under the critical dosages stated for rectum, bladder and femoral heads for each technique, the doses given to the critical organs were higher with the MLC technique. Regarding the late toxicity and the critical organ doses, each of these shaping methods is suitable for the definitive irradiation of prostate carcinoma with six-field technique. [Turk J Cancer 2006;36(3):126-132].

KEY WORDS:

Prostate cancer, conformal radiotherapy, toxicity, multileaf collimator

INTRODUCTION

As being the most commonly diagnosed male malignancy, prostate cancer requires meticulous treatment setups to ensure proper coverage of the target volume while reducing the doses to the normal tissues (1-3). Along surgery, radiotherapy is the most important and the most preferred form of the curative treatment, especially in the localized disease. Dose escalation strategies through the three-dimensional conformal radiotherapy (3D-CRT) are superseding conventional techniques in the treatment of prostate cancer and results with a better therapeutic outcome profile (4). While conformal radiotherapy techniques are being widely used in prostate cancer, some points like the optimal number of beams, field arrangements and shaping methods to spare the adjacent normal tissues like rectum, bladder and femoral heads still remains controversial (3). Each technique has its advantages and disadvantages with respect to the ease of treatment set up, degree of sparing of nominated surrounding normal tissues and delivery and treatment verification (1,3, 4-6).

An important matter of debate in the 3D-CRT planning is the optimum method of shaping (7,8). Previous planning studies have used conformally blocked treatment fields whose shape follows accurately the beams-eye-view (BEV) of the planning target volume (PTV). Because these devices are more convenient and faster to use, many of the treatment centers use MLC to shape treatment portals instead of C blocks. In this case the provided PTV shape do not exactly follow the beam's-eye-view of PTV, but instead makes a stepped approximation to the PTV shape, having MLC leaf steps width being 10 mm at the isocenter. (9,10). Apprehension is mainly due to the undulating dose pattern of the field edge that may be problematic especially when a critical structure exists in close proximity to the field edge. In this situation the C block gives a better result than MLC (11). This approximation of the PTV causes the doses to be lower than wanted, especially near the field edges.

It's the objective of this study to evaluate the optimum method of blocking configuration for localized prostate carcinoma comparing a group of patients' treatment plans generated with MLC, against corresponding plans generated with C blocks. The effects of set up variations are not taken into account. Dose volume histograms of the PTV, rectum, femoral heads and bladder were used to assess our findings.

MATERIAL AND METHODS

Six patients with histologically proven localized prostate cancer and treated with conformal irradiation between January 2001 and September 2002 were evaluated retrospectively. They were all chosen to assess the differences between C blocks and MLC configuration during the definitive radiation therapy of prostate carcinoma with six field technique. In phase I; a dose of 45-59.4 Gy (mean: 49.5 Gy) was given to both seminal vesicles and the prostate with a daily dose of 1.8 Gy. Following the initial phase, the total dose for the prostate was raised up to 68.4- 72 Gy (mean: 70.2 Gy) with an additional boost. All the patients received conformal radiotherapy with the blocking configurations provided with MLC technique.

Simulation with Computerized Tomography Extension (Nucletron Oldheft) in a supine position with 1 cm scanning interval through the treatment field and 0.5 centimeter intervals were applied in the target volume region to all of the patients. After the simulation procedure was planned with a full bladder and an empty rectum, the CT images were automatically transferred to a treatment planning system (Theraplan plus 3000). All of the organs of interest; prostate, rectum, seminal vesicles, bladder and femoral heads were delineated on the treatment planning system as well as the clinical target volume (CTV) and PTV.

The clinical target volume was defined as the entire prostate and seminal vesicles. Only one patient did not fulfill the risk criteria to irradiate the seminal vesicles so only prostate was included in the target volume. A one centimeter margin as seen on the scan and approximately 1 cm margins in the transverse and superior, inferior directions to fit the beam penumbra and the organ's motion to cover the PTV was added. In the boost phase the CTV plus a 0.5 cm margin has been applied as PTV.

Treatment plans were constructed with a Theraplan plus 3000 for 15 MV photons to be delivered with Siemens Primus linear accelerator. The Siemens Primus Linear accelerator has a multileaf collimator system. The Siemens MLC leaves are double focused, i.e., they provide correct beam divergence in both perpendicular directions. The Siemens MLC system consists of 29 pairs of tungsten leaves. The leaves are mounted in which they replace the

lower jaws (the X jaws) of the standard collimator. The Siemens MLC provides a maximum field size of 40x40 cm² at isocentre. Each leaf of the inner 27 pairs has a nominal projected wide of 1 cm at isocentre. (100 cm source-to- axis distance, SAD) The outermost pairs (No.s 1 and 29) consist of wide leaves that project 6.5 cm wide fields at isocentre. These 29 pairs of leaves can be moved independently with a precision of one millimeter.

While these patients had already been treated with a chosen target volume generated with MLC; configuration of therapy plans were delineated for each patient with each of the two blocking methods. The first was a 6 field irradiation technique of the prostate. The six field arrangement was coplanar consisting of two lateral and four oblique fields at 45° above and below the lateral fields. The boost phase of the six-field beam arrangement was consisted of the same plan but with a reduced boost volume. The beam weights were chosen as 0.13, 0.25, 0.12, 0.12, 0.25 and 0.13 beginning from the first anterior oblique field at the clockwise direction. The Multileaf collimation planning was applied with respect to the created PTV using an automatic procedure via touching the field edge at the centre of the leaf on the treatment planning system. The leaf width was 10 mm at the isocentre and the transmission factor was 5%. The aim was to cover the PTV with the 95% isodose, with 5% upper and 5% lower limits of acceptability. The second plan was reconstructed with the same beam arrangements but with different shaping configurations. Cerrobond blocking planning with transmission of 3% was applied to the same initial and boost fields. The isocentre was located at the centre of the PTV for all plans and no wedges were used in none of the plannings. The created blocks were added to the appropriate fields and the dose distribution was normalized to 100% at the isocentre.

Both types of fields were fitted to beams' eye view (BEV) of the PTV using Theraplan software, which then produced beam blocks for the Theraplan plus 3000 treatment planning system. Asymmetric fields were used when indicated.

Dose statistics and dose volume histograms were used to compare the resulting dose distributions. The dose was calculated using the pencil beam algorithm in the Theraplan

plus treatment planning system. All doses were normalized to 100% at the isocentre. Dose-volume histograms (DVH) were also calculated using the Cumulative Dose Volume Histograms algorithm for PTV; rectum, bladder and femoral heads. The DVH's for MLC shaping and conformal blocks were compared in terms of tissue volumes treated at given dose points (for ex. V40Gy, V50Gy, V70Gy...) and the differences in irradiated volumes of MLC and conformal block configurations were assessed for each critical structure using a nonparametric Wilcoxon test (12). The mean dose volume histograms for the organs of interest were generated using Excel program, Windows 2000 Edition.

RESULTS

Figure 1 shows the mean DVH of the six-field plans for prostate carcinoma for PTV and figure 2 represents the mean DVH's femoral heads, bladder and rectum using both cerrobond blocks and MLC technique. The six-field plan with MLC provides a suitable PTV coverage with cerrobond blocking. The mean DVH of rectum is better with individualized blocks compared to the MLC technique as seen on the mean rectal DVH (Figure 2). Although the relative difference is larger at moderate doses as seen on the histogram, it becomes smaller at the high dose region (60-70Gy) and the two lines intersect at the critical high dose points.

The six-field plan with MLC irradiates a larger volume of bladder (V30Gy-). But as it provides a similar coverage of the volume of interest in the 30-50 Gy regions like rectum, in the high dose regions, the lines presenting the irradiated volumes of MLC and cerrobond blocking become closer.

Similarly femoral heads are irradiated with higher doses with MLC. The difference of the low to moderate dose region becomes smaller in the 60-70Gy and becomes 0.

Table 1 shows the mean statistics of the volumes corresponding to given dose points for MLC and customised blocking plans. All the mean volumes irradiated in dose points for rectum, bladder and femoral heads are under critical dosages.

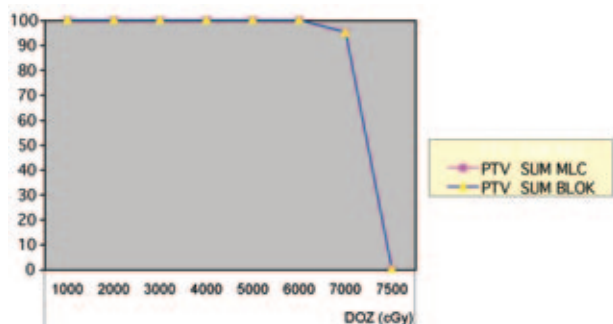


Fig 1. Mean dose volume histograms for PTV

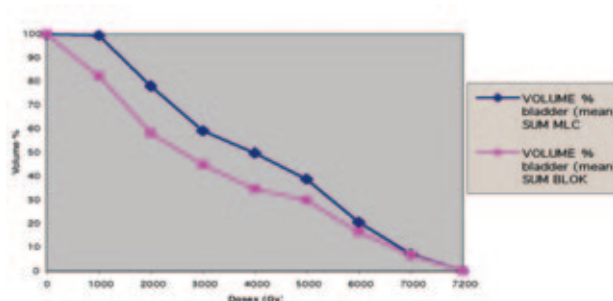


Fig 2. Mean dose volume histograms for the critical normal adjacent structures

Table 1			
Mean volumes of interest at given dose points			
	MLC (% volume)	Block (%volume)	P
Rectum			
V30Gy	57.08	52.41	>0.05
V40Gy	52.33	46.00	0.04
V50Gy	42.41	35.91	0.04
V60Gy	27.83	24.83	>0.05
V70Gy	12.66	10.50	>0.05
Bladder			
V30Gy	59.12	44.90	0.04
V40Gy	49.98	34.67	0.02
V50Gy	38.84	29.99	>0.05
V60Gy	20.74	16.50	>0.05
V70Gy	7.18	6.76	>0.05
Right femur heads			
V50Gy	11.37	9.00	>0.05
V60Gy	1.89	0.6	>0.05
Left femur heads			
V50Gy	21.20	17.17	>0.05
V60Gy	6.68	5.34	>0.05

DISCUSSION

Shaping of the fields can be achieved using cerrobond customized conformal blocks, a multileaf collimator (MLC) or a mini/micro MLC (13,14). MLC's are commercially available offers for conformal fields, and rapid treatment procedures but beam shaping is less precise due to 10 mm stepping of the leaves at isocentre (14).

This study is planned to analyze and compare the dose volume relationship of the prostate and the adjacent normal structures with each of the two shaping techniques. The DVH's revealed that a complete coverage of the prostate and seminal vesicles is achieved and the PTV was suitably delineated with two techniques as reported by Lo Sasso et al. and Adams et al. (10,15).

The rectum seems to be the most critical dose limiting structure in prostate radiotherapy. The risk of developing rectal complications increased with larger target volumes (16,17). In the previous studies, the late rectal toxicity was seen particularly at doses greater than 60 Gy with 3D-CRT (2,18,19). Recently, Huang et al. (4) identified the optimal cut points that most significantly discriminate those patients at high risk of late toxicity from those patients at low risk. To reduce the risk of late toxicity; < 40% of the defined rectal volume should receive 60 Gy and < 25% should receive 70 Gy and < 5% should receive 78 Gy. The rectal toxicity related data shows that, between the low to moderate doses range, even a larger percentage volume of rectum is irradiated and toxicity does not occur. This may indicate that a large surrounding region of intermediate dose may interfere with the ability to repair the effects of central high dose region.

In our data, the mean DVH of rectum was higher for the plans generated with MLC than cerrobond blocks for the irradiated volumes of rectum at the dose points of V40Gy, V50Gy, statistically ($p=0.04$). On the other hand the dose points for V60 and V70 that are adjusted to be the critical volumes of interest did not differ significantly. Whilst the percentage of the volume irradiated at all dose levels with MLC was worse than the other plan; none of the shaping configurations did show a volume of dose point greater than the accepted critical cut points for the DVH of the rectum.

Our data revealed that the mean volumes irradiated at dose points for 30 Gy and 40Gy showed a statistical difference for bladder. Whilst irradiating larger volumes with MLC in the moderate (30-50Gy) dose region, at the higher dose points, the irradiated volumes with MLC did not differ from conformally individualized configurations which indicated that with each of the blocking techniques, the critical dose for the bladder was not achieved. As it's stated by some of the investigators, none of them was able to find out any correlation between the irradiated volume and bladder toxicity, and it was suggested that the bladder toxicity is to be assessed as in the case of rectum (7,20).

The complication probability for the femoral heads is in fact gathered from the calculations of NTCP and this issue is not as clinically relevant as for rectal morbidity (21). Khoo and associates (3) adopted a non-pragmatic indicator of femoral head tolerance. This was that, no more than 10% of the femoral head volume should receive a dose greater than 52 Gy and if a prescription dose of 74 Gy is administered, than a percentage volume of greater than 70% was required to be below the threshold of 100%. None of the configurations of the plans irradiated a volume greater than 10% at 52 Gy for the right femur. Left femur had been irradiated with a higher mean dose distribution than 10% for the doses of greater than 52 Gy, but since it did not reach a statistical difference, the conformal shaping method was slightly better.

Several groups investigated normal tissue and organ dose volume effects for conformally irradiated volumes. Adams et al. (15) stated the normal tissue increases were due to larger penumbral region required for MLC as in the case of stereotactically irradiated brain tumors. Similarly Fernandez et al. (22), reported that the 5.5% of the treatment plans generated with MLC shaping could not achieve an adequate coverage of the target volume especially for lymphoma and brain tumors because of the difficulties in the shielding of critical structures such as back of the eye where the larger penumbra caused inadequate irradiation of the target volume. One of the most problematic dosimetric differences between the two shaping techniques is the penumbra width. The irregularity of the field edge introduced by MLC leaf widths of 1-1.25 centimeter relative to the smoothly verifying C blocks, is a potential disadvantage.

The effective penumbra which is defined as the difference between a line connecting the crests of the 80% isodose level and a line connecting through of the 20% level has been reported to be 3-5 mm larger than the corresponding values for cerrobond shaped fields (10). Secondly the zigzag arrangement of the leaf edges imprints it's own on the penumbra which appears as the 'scalloping effect' of the isodose lines, for a MLC field. In fact this effect is even smaller than expected due to some other factors. Photon and electron scatter in the patient is one of these factors. The 90% isodose line have minimal 'scalloping' as compared to the 50% isodose line since more of the secondary electrons in the 50% region are due to interactions of primary photons closer to the edge of the aperture. As reported by Lo Sasso et al. (10) and Powlish et al. (14), when the individual radiation beams are composed in a multifield treatment, the effect of scalloping dose distributions are moderated by the dose distributions from the other fields. When daily set up variations are included in the

analysis, the penumbra for the block edge is only minimally different than the penumbra for an MLC positioned with maximum stepping (leaf displacement relative to its neighbor is equal to the leaf width) and setup variations over a period of time tend to smooth the MLC beam edges (23-25).

Our analysis suggest that the MLC dosimetry is less favorable than that of the cerrobond blocks in the treatment of six-field irradiation of prostate carcinoma on the computerized planning system without daily setup variations taken into account. However, none of the normal tissues e.g. rectum, bladder or femoral head were irradiated to the critical doses and thus with each of the beam shaping configurations, higher volumes did not receive critical doses of irradiation. Even though the scalloping effect and larger penumbra, MLC shaped fields seems to be problematic features; it's reported that when the set up uncertainties and the multifield treatments are taken into account, these features would also reduce the differences between using conformal blocks and MLC.

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