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Case Study

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Author for correspondence:
Poonam Yadav, Department of Human Oncology, University of Wisconsin School of Medicine and Public Health, 600 Highland Avenue, K4/B74, Madison, WI, USA.
Tel: 001 608-235-2594. Fax: 001 608-263-0990.
E-mail: yadav@humonc.wisc.edu

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Radiotherapy treatment planning for prostate and nodes using variable planning ring

Poonam Yadav[1], Yue Yan[2] and Bhudatt R. Paliwal[1]

[1]Department of Human Oncology, University of Wisconsin School of Medicine and Public Health, Madison, WI, USA and [2]Department of Radiation Oncology, St Jude Children's Research Hospital, Memphis, TN, USA

Abstract

Background: Prostate cancer is one of the most common solid malignancies and has a high morbidity rate. The uncertainty of the prostate location compromises the overall treatment plan optimisation. To account for the location uncertainty, the radiation oncologist needs to expand the margin of the planning target volume (PTV), which may increase the radiation toxicity to organs in proximity.
Materials and methods: In this study, we investigated the quality of treatment plans for a patient with different ring sizes (2 and 3 cm). A small ring-shaped structure circumferentially around the PTV helps in defining the location of PTV. Prostate and pelvic node plans were analysed with dose prescription to 99% of PTV.
Results: Additional ring-shaped structures led to more conformal dose coverage for target with reduced radiation side effects to nearby organ at risk (OAR). Expected treatment time was slightly higher for 2 cm ring compared to 3 cm ring. In case of prostate, expected duration was 4% higher, while for node plan, expected duration for 2 cm ring was 16% higher compared to 3 cm ring plan.
Conclusions: It was observed that using a smaller size ring can lead to improved dose sparing to OAR with same target coverage as with larger dimension ring. The composite plans do not show any clinically significant difference in dose to OARs.

Introduction

Prostate cancer is one of the most common solid malignancies with high morbidity rate.[1] There are several treatment alternatives including prostatectomy, brachytherapy, external beam radiation or a combination of two or more. Radiotherapy is commonly used to treat localised prostate cancer.[2]

In radiotherapy, defining the tumor margin is a critical factor affecting the treatment outcome. In order to contour a tumor, following regions of interest should be specified: (1) gross tumor volume (GTV) that covers the primary tumor; (2) clinical target volume (CTV) to define a margin around the GTV to cover microscopic disease and (3) planning target volume (PTV), which contains margin around CTV to account for set-up uncertainty.[3–5] The rationale of different contours is to consider set-up errors and internal target motion without compromising target coverage. The margins must also facilitate conformal avoidance of the normal tissues. The uncertainty of prostate position limits the optimisation of conformal radiotherapy (CRT), and in order to account for positional uncertainties, PTV should be expanded.[6] The development of the three-dimensional CRT and intensity modulate radiotherapy has enabled the delivery of escalated doses to the tumor target while simultaneously sparing the surrounding normal tissues.[7,8]

It is observed that a small ring-shaped structure circumferentially around the PTV permits the planning programme to make the higher isodose curves more conformal to the PTV and limits the maximum dose on tumor volume.[9,10] Presently, ring of different shapes and sizes is used by dosimetrists to improve plan quality.

In this case study, we investigated the dosimetric differences in treatment plans with rings of two different diameters (2 and 3 cm) for prostate and prostate nodes using tomotherapy.

Case Description

The patient was scanned on a helical computed tomography (CT) system with 2.5 cm slice thickness. The kV CT images were exported to the Pinnacle[3] 8.1 treatment planning system (Philips Medical Systems, Fitchburg, WI, USA) for contouring. The patient was treated for the prostate and pelvic nodes in 75·6 Gy (30·6 Gy/17 fractions with successive 45 Gy/25 fractions boost). Attending physician contoured the prostate, seminal vesicles, bladder, rectum, femoral heads,

Table 1. Treatment planning parameters for all prostate and node plan

Parameters	Prostate plan	Node plan
Prescription (Gy)	30·60	45
Number of fractions	17	25
Field width (cm)	2·5	2·5
Pitch	0·430	0·430
Planning modulation factor (Actual)	2·0 (1·734)	2·0 (1·543)
Plan calculation grid (cm^2)	Normal (0·450 × 0·450)	Normal (0·450 × 0·450)

Table 2. Planning constraints used in prostate plan for 2 and 3 cm rings

Prostate - Tumor constraints				
Organ name	Max dose constr. (Gy)	DVH vol (%)	DVH dose (Gy)	Min dose constr. (Gy)
PpV75_6	30·6	99	30·6	30·6
Sensitive structure constraints				
Organs name	Max dose constr. (Gy)	DVH vol (%)	DVH dose (Gy)	
Bladder	30·6	50	16·2	
Rectum	30·6	40	11·5	
Colon	30·6	35	16·2	

DVH, dose volume histogram.

Table 3. Planning constraints used in pelvic node plan for 2 and 3 cm rings

Nodes - Tumor constraints				
Organs name	Max cose constr (Gy)	DVH vol (%)	DVH dose (Gy)	Min dose constr. (Gy)
Pp_scV45	45	99	45	45
Node PTV	45	95	45	45
Sensitive structure constraints				
Organs name	Max dose constr (Gy)	DVH vol (%)	DVH dose (Gy)	
Bladder	45	85	11·3	
Rectum	45	70	11·3	
Colon	45	80	11·3	
Bowel	45	35	31·5	
Abdomen	21	1	21	

DVH, dose volume histogram.

Table 4. Delivery parameters for different ring diameters' plans

	Prostate values		Nodes values	
Parameters	3 cm ring	2 cm ring	3 cm ring	2 cm ring
Expected duration (seconds)	222·4	232·5	454·1	542·2
Gantry rotations	11·1	8·9	22·7	21·7
Gantry period (seconds)	20	29	20	25
Monitor unit	3,122	3,249	6,529	7,769
Couch travel (cm)	12	9·6	24·6	23·3
Couch speed (cm/seconds)	0·054	0·041	0·054	0·043
Field widths	5·8	4·8	10·8	10·3

colon, bowel and abdomen. Apart from these structures, an external posterior block to reduce rectal dose was also contoured by the dosimetrist. This block is basically a dummy volume around the PTV to improve conformity in high-dose regions and to reduce dose in normal tissues. For planning, the CT datasets and the contours were transferred to the tomotherapy planning station (TomoTherapy Inc., Madison, WI, USA) using a DICOM RT export window. The patient was treated using two different plans for prostate and nodes in sequence. Patient was treated with plans (prostate and node) utilising ring-shaped contours with a diameter of 3 cm. Two more plans (one for prostate and other for pelvis nodes) were generated using 2 cm ring for retrospective study in order to analyse the impact of reducing the ring diameter in treatment plans. Also, a composite plan (combined dose volume histogram (DVH) of prostate and pelvic node plans) was generated using in-house software. The planning parameters used for plans are tabulated in Table 1. The dose was prescribed to 99% of the PTV for both prostate and node plan.

This study was conducted to demonstrate the dosimetric differences in the prostate and pelvic node plans with two different ring dimensions (2 and 3 cm). The optimisation parameters used for both plans are shown in Tables 2 and 3.

In order to do a fair comparison, the same optimisation parameters were used for both plans.

Results and Discussion

It is observed that the plan with a smaller ring structure (2 cm) shows better sparing of the organs at risk (OARs) for prostate plans (Figure 1). However, for node plan, no significant difference is observed for OAR (ROI's) except for femoral heads. The dosimetric parameters for OARs in prostate and nodes for 2 and 3 cm are plotted in histogram shown in Figures 1 and 2. Hotspots greater than 105% were present for 2 cm plan in nodes but not for 3 cm plan.

Figure 3 shows the isodose distribution for prostate with 2 and 3 cm rings.

However, for 3 cm plan, these hotspots are absent. Similar results are observed in composite DVHs. The differences in the delivery parameters are shown in Table 4. As demonstrated in Table 4, monitor units and gantry period are significantly increased, if a smaller diameter ring is used.

Expected duration was higher for both prostate and node plans with 2 cm ring compared to 3 cm ring.

Percentage difference between 2 and 3 cm prostate plans was slightly more for field width and couch travel compared to node plans.

Conclusion

Using a smaller size ring improves the dose to OAR without compromising tumor coverage. Hotspots can be eliminated with additional constraints on the PTV. Also, the composite plans do

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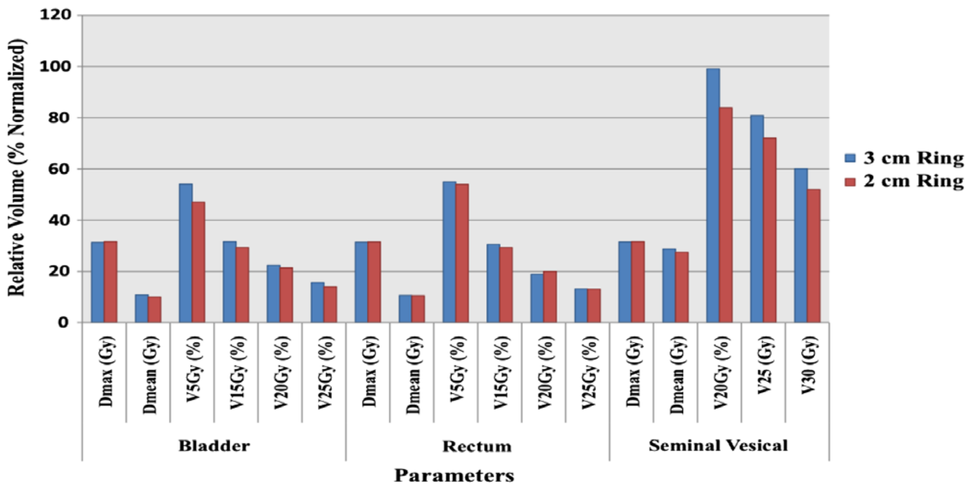

Figure 1. Dosimetric parameters for bladder, rectum and seminal vesicles in prostate plans using 2 and 3 cm rings.

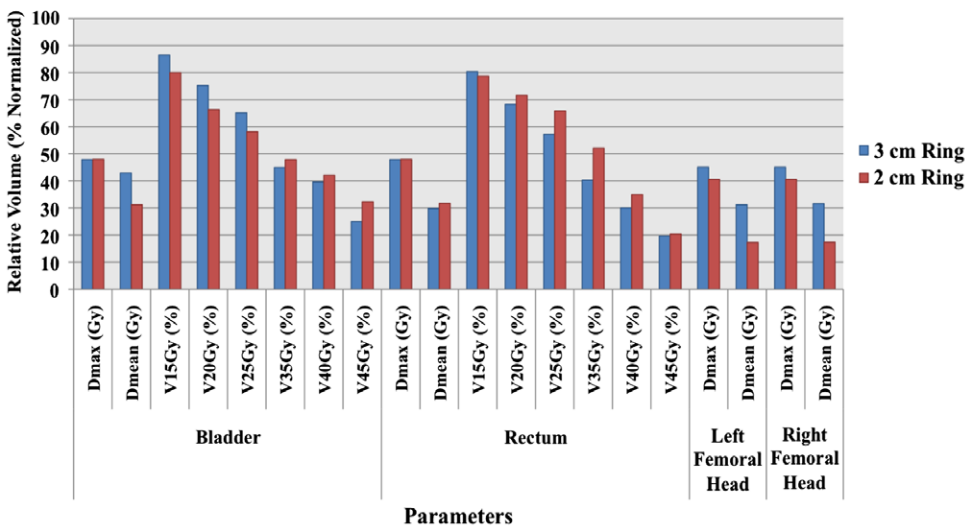

Figure 2. Dosimetric parameters for bladder, rectum, left and right femoral head in pelvic plans using 2 and 3 cm rings.

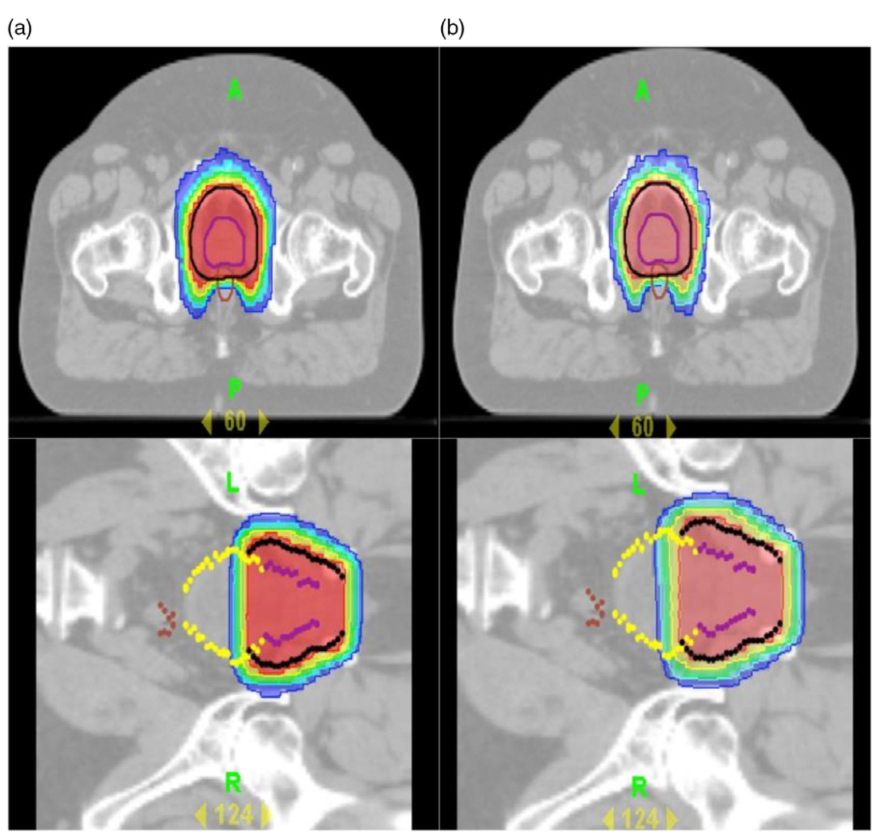

Figure 3. Isodose distribution on transverse and coronal planes for 2 cm (a) and 3 cm ring (b) in prostate plan. Red, yellow, green and blue represent 100, 95, 90 and 80% isodose line, respectively.

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not show any significant difference in dose to OAR. Further studies should be conducted to explore the feasibility of compact ring for other potential tumor sites too, besides prostate.

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