Correlation of clinical target volume and the margins to define planning target volume with beam arrangements for three-dimensional conformal radiation therapy delivery for prostate cancer

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Background. *A conceptual study was undertaken to correlate the clinical target volume and the margins to define the planning target volume with the beam arrangements for a three-dimensional conformal radiation therapy delivery on two patients with prostate cancer having considerably different prostate shapes and volumes.*

Material and methods. *The clinical target volume was defined as prostate and seminal vesicles. Uniform margins of 0.4, 0.8 and 1.2 cm were added around the clinical target volume to define three planning target volumes. Three well-established coplanar beam arrangements were simulated for all planning target volumes. Dose-volume histograms were calculated and quantitatively compared.*

Results. *The mean dose (Dm) for PTVs ranged from 98.7 to 99.9%, with standard deviations ranging from 1.5 to 1.7%. Plan I appeared to be the best considering the Dm for the rectum, whereas Plan II appeared to be the best considering V95 (fraction of volume receiving a dose higher than 95% of the isocenter dose for the rectum). Plan III appeared to be the best considering the Dm and V95 for the bladder and also considering the Dm and V50 for the femur.*

Conclusions. *This conceptual study suggested that the differences in shapes and volumes of planning target volume might be taken into consideration in an attempt to individually establish the optimum beam arrangements for three-dimensional conformal radiation therapy delivery in prostate cancer.*

Key words: prostatic neoplasms radiotherapy; radiotherapy, conformal

Received 28 November 2005
Accepted 12 December 2005

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Introduction

A three-dimensional conformal radiation therapy is characterized by the conformation of the radiation dose to the target volume besides the reduction of the radiation dose to the normal tissues at risk.[1] The three-dimensional conformal radiation therapy requires the accurate delineation of gross tumor volume (GTV) and meticulous identification of the margins to define the clinical target volume (CTV) and the planning target volume (PTV).[2] The design of the beam arrangements for the three-dimensional conformal radiation therapy delivery could be hampered by the variations in the shape and the volume of GTV as well as the variations in the margins to define CTV and PTV.

The aim of this conceptual study was to correlate CTV and the margins to define PTV with the beam arrangements for the three-dimensional conformal radiation therapy delivery on two descriptive patients with prostate cancer having considerably different prostate shapes and volumes.

Material and methods

Of two patients with localized prostate cancer investigated in this study, Patient I had a concave shaped prostate with a comparatively small CTV of 48.3 cm^3 and Patient II had a non-concave shaped prostate with a comparatively large CTV of 82.1 cm^3. The patients were positioned supine with a full bladder and immobilized in a molded foam cradle (Redifoam, Med-Tec Inc., Orange City, United States of America). Following the administration of the contrast material into the bladder and the rectum, transverse computed tomography images of the pelvis were obtained on a dedicated scanner (IQ-TC, Picker International, Cleveland, United States of America) with a slice thickness of 0.2 cm (at 0.2 cm steps) throughout the region containing the target volume (from the bottom of the sacroiliac joints to the penile urethra) and a slice thickness of 0.5 cm (at 0.5 cm steps) throughout the regions above and below the region containing the target volume. The prostate, the seminal vesicles, the bladder (from the apex to the dome), the rectum (from the anus at the level of the ischial tuberosities for a length of 15 cm) and right femur (to the level of the ischial tuberosities) were outlined on a virtual simulation workstation (Acqsim, Picker International, Cleveland, United States of America).

With respect to the International Commission on Radiation Units and Measurements (ICRU) Report 50,[2] GTV was defined as the prostate and CTV was defined as the prostate and the seminal vesicles. Uniform margins of 0.4 cm (Margin I), 0.8 cm (Margin II) and 1.2 cm (Margin III) were added around CTV through the automatic volume expansion to take into account the variations in the shape and the volume of CTV as well as to take into account the uncertainties in patient positioning. Margin I, Margin II and Margin III defined PTV I, PTV II and PTV III, respectively. To define the block edges, a margin of 0.7 cm was added around PTVs to account for the effect of the penumbra.

Three well-established coplanar beam arrangements were simulated for PTV I, PTV II and PTV III. Plan I had an anteroposterior field and two lateral 30° wedged fields, Plan II had an anteroposterior field, a posteroanterior field and two lateral fields and Plan III had an anteroposterior field, a posteroanterior field, two anterior oblique fields and two posterior oblique fields. Dose distributions for equally weighted fields were calculated for 18 MV photons and normalized at the isocenter on a three-dimensional treatment planning system (Cadplan, Varian-Dosetek Oy, Finland). The reference dose was considered as 95% of the isocenter dose. Dose-volume histograms (DVHs) for PTV, the bladder, the rectum and the femur were calculated. For the quantitative comparison of DVHs, the mean dose (Dm) and the fraction of volume receiving a dose higher than 95% of the isocenter dose (V95) were considered for the rectum and the bladder and Dm and the fraction of volume receiving a dose higher than 50% of the isocenter dose (V50) was considered for the femur.

Results

The Dm for PTVs ranged from 98.7 to 99.9%, with standard deviations ranging from 1.5 to 1.7%.

Considering Dm for the rectum, Plan I appeared to be the best and Plan III appeared to be the worst beam arrangement regardless of the shape and the volume of the prostate and regardless of the margin added around CTV. Considering V95 for the rectum, Plan II appeared to be the best and Plan III appeared to be the worst beam arrangement for Margin I and Margin II while Plan III appeared to be the best and Plan I appeared to be the worst beam arrangement for Margin III for Patient I, whereas Plan I appeared to be the best and Plan III appeared to be the worst beam arrangement regardless of the margin added around CTV for Patient II.

Considering Dm for the bladder, Plan III appeared to be the best and Plan II appeared to be the worst beam arrangement regardless of the shape and the volume of the prostate and regardless of the margin added around CTV. Considering V95 for the bladder, Plan III appeared to be the best beam arrangement for Margin I and Plan I appeared to be the best beam arrangement for Margin II and Margin III while Plan II appeared to be the worst beam arrangement regardless of the margin added around CTV for Patient I, whereas Plan I appeared to be the best and Plan II appeared to be the worst beam arrangement regardless of the margin added around CTV for Patient II.

Considering both Dm and V50 for the femur, Plan III appeared to be the best and Plan I appeared to be the worst beam arrangement regardless of the shape and the volume of the prostate and regardless of the margin added around CTV.

Dm and V95 values for the rectum and the bladder and Dm and V50 values for the femur are shown in Table 1 and Table 2, respectively, for Patient I and Patient II.

Discussion

For patients with prostate cancer treated with the three-dimensional conformal radiation therapy, a wide range of variation has been reported for CTV as dictated by the volume of the prostate. Forman *et al*. have reported the volume of the prostate to range from 10 to

Table 1. Comparisons of Dm and V95 values for the rectum and the bladder and Dm and V50 values for the femur for different PTVs with different beam arrangements for Patient I.

	Plan I			**Plan II**			**Plan III**		
	PTV* I	PTV II	PTV III	PTV I	PTV II	PTV III	PTV I	PTV II	PTV III
Bladder									
Dm**	29.39	34.92	37.92	34.41	39.36	42.31	26.21	31.85	37.08
V95***	11.09	19.46	30.33	14.57	22.29	35.01	10.76	19.79	32.18
Rectum									
Dm	25.05	30.74	33.69	28.27	33.19	35.51	29.33	34.75	36.92
V95	18.35	32.12	43.48	18.24	30.48	42.61	20.54	35.72	42.19
Femur									
Dm	30.25	34.10	37.41	22.68	26.29	37.80	19.48	23.59	26.64
V50****	76.60	90.21	100.42	59.72	75.47	86.56	18.65	32.00	40.70

*PTV: Planning target volume, **Dm: The mean dose, ***V95: The fraction of volume receiving a dose higher than 95% of the isocenter dose, ****V50: The fraction of volume receiving a dose higher than 50% of the isocenter dose.

Table 2. Comparisons of Dm and V95 values for the rectum and the bladder and Dm and V50 values for the femur for different PTVs with different beam arrangements for Patient II.

	Plan I			Plan II			Plan III		
	PTV* I	PTV II	PTV III	PTV I	PTV II	PTV III	PTV I	PTV II	PTV III
Bladder									
Dm**	37.36	42.21	46.56	42.04	46.77	50.40	34.76	39.98	45.54
V95***	13.18	20.38	36.08	18.42	29.35	44.00	13.37	23.00	39.54
Rectum									
Dm	42.43	50.35	57.00	50.71	57.03	61.36	51.05	58.32	63.67
V95	2.96	9.68	16.75	5.04	11.97	19.64	5.31	12.04	20.92
Femur									
Dm	42.65	45.05	47.81	32.21	34.02	36.42	23.45	25.89	28.73
V50****	130.36	138.55	146.86	120.43	129.22	138.97	6.56	16.20	46.85

*PTV: Planning target volume, **Dm: The mean dose, ***V95: The fraction of volume receiving a dose higher than 95% of the isocenter dose, ****V50: The fraction of volume receiving a dose higher than 50% of the isocenter dose.

155 cm^3 (median, 52 cm^3) in patients with prostate cancer treated with three-dimensional conformal radiation therapy.[3] In the intervening years since the publication of the ICRU Report 50 in 1993, the acceleration in the clinical application of three-dimensional conformal radiation therapy has necessitated a more accurate definition of PTV. In 1999, the ICRU Report 62 has been published as a supplement to Report 50, addressing the different sources of uncertainties to be taken into account in delineating PTV.[4]

The ICRU Report 62 has defined an internal margin (IM) to take into account the uncertainties in the shape and the volume of CTV and a set-up margin (SM) to take into account the uncertainties in patient positioning. While IM has mainly been related to the physiological variations that have been difficult or impossible to control, SM has mainly been related to the technical factors that could have been reduced by the more accurate immobilization and the set-up of the patient, as well as the improved mechanical stability of the treatment machine.[4] Tinger *et al*. have reported margins ranging from 0.7 to 1.1 cm to be added around CTV to encompass the overall uncertainties with a 95% probability and margins ranging from 1.0 to 1.6 cm to be added around CTV to encompass the overall uncertainties with a 99% probability.[5]

The three-dimensional conformal radiation therapy for prostate cancer has traditionally been delivered through well-established coplanar three-field, four-field or six-field beam arrangements.[6-8] Although these beam arrangements have been compared in terms of dose distributions to the normal tissues at risk through dose-volume histograms, the different sources of uncertainties to be taken into account in delineating PTV have generally not been appreciated.[9,10] Therefore, the contributions of the shape and the volume of the prostate and the magnitude of the margin defining PTV to the selection of the beam arrangements for the three-dimensional conformal radiation therapy delivery have not been independently described.[11,12]

In this conceptual study, the differences in the shapes and the volumes of PTVs for the investigated patients underlined the establishment of different beam arrangements as the optimum beam arrangement for different patients. However, the same beam arrangements were established as the optimum beam arrangement for a given patient, regardless of the increases in the magnitudes of the margins defining PTVs. These findings suggest that the inherent characteristics of the patients, such as the shape and the volume of the prostate, might lead to more critical contributions for the establishment of the optimum beam arrangements when compared to the margins typically added around the target volumes based on the established policies of the institutions. Further studies of a larger scale are warranted to confirm that the selection of the beam arrangements for three-dimensional conformal radiation therapy delivery in patients with prostate cancer having considerably different prostate shapes and volumes should call for individual rather than class solutions.

Acknowledgement

This study has been presented at the "3rd Takahashi Memorial International Workshop on Three Dimensional Conformal Radiotherapy" in Nagoya, Japan in 2001.

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