Clinical implementation of high precision radiotherapy for urogenital tumours

Meijer, G.J.

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Chapter 2

Comparison of prostate cancer treatment in two institutions, a quality control study

Coen Rasch, Peter Remeijer, Peter C.M. Koper, Gert J. Meijer, Joep C. Stroom, Marcel van Herk and Joos V. Lebesque

Comparison of prostate irradiation

Abstract

Purpose:
To minimize differences in the treatment planning procedure between two institutions within the context of a radiotherapy prostate cancer trial.

Patients and methods:
Twenty-two patients with N0 M0 prostate cancer underwent a computed tomography (CT) scan for radiotherapy treatment planning. For all patients, the tumor and organs at risk were delineated, and a treatment plan was generated for a three-field technique giving a dose of 78 Gy to the target volume. Ten of the 22 cases were delineated and planned in the other institution as well. The delineated volumes and dose distributions were compared.

Results:
All treatments fulfilled the trial criteria. The mean volume ratio of the gross tumor volumes (GTVs) in both institutions was 1.01, while the mean volume ratio of the planning target volumes (PTVs) was 0.88. The three-dimensional (3D) PTV difference was 3 mm at the prostate apex and 6-8 mm at the seminal vesicles. This PTV difference was mainly caused by a difference in the method of 3D expansion, and disappeared when applying an improved algorithm in one institution. The treated volume (dose ≥ 95% of isocenter dose) reflects the size of the PTV and the conformity of the treatment technique. This volume was on average 66 cm$^3$ smaller in institution A than in institution B; the effect of the PTV difference was 31 cm$^3$ and the difference in technique accounted for 36 cm$^3$. The mean delineated rectal volume including filling was 112 cm$^3$ and 125 cm$^3$ for institution A and B, respectively. This difference had a important impact on the relative dose volume histogram (DVH) of the rectum.

Conclusion:
Differences in GTV delineation were small and comparable to earlier quantified differences between observers in one institution. Different expansion methods for generation of the PTV considerably influenced the amount of irradiated tissue. Strict definitions of target and normal structures are mandatory for reliable trial results.
Key words:
Prostate Cancer; Quality Control, Radiotherapy Treatment Planning, Interobserver variation.
Comparison of prostate irradiation

Introduction

Dose escalation affects the outcome of radiation therapy for localized prostate cancer (1-5). Perez et al. (1, 2) demonstrated a reduction of local failure with higher dose. More recently, this was confirmed by several other investigators (3, 4, 6). Zelefsky et al. (3) reported a higher prostate-specific antigen (PSA) relapse-free survival in patients with intermediate and unfavorable (>T2, pretreatment PSA >10 ng/ml) prognosis with irradiation to a dose of more than or equal to 75.6 Gy versus a lower dose. Hanks et al. (4) reported at the same time a 5-year biologically disease-free survival of 35% at 70 Gy versus 75% at 76 Gy for patients with a pretreatment PSA of 10-19.9 ng/ml.

The disadvantage of a higher tumor dose is a higher dose to the surrounding tissues. The most frequently reported normal tissue complications of radiation treatment of the prostate are urological and gastrointestinal (GI). The high dose, as reported by Perez et al., Schultheiss et al., and Hanks et al. (1, 4, 7), resulted in both a higher GI and urological complication rate. However, not only the dose determines the complication rate; the volume of irradiated rectum affects the risk of GI complications as well (8-13). Boersma et al. (10) and Hartford et al. (12) demonstrated a dose-volume relationship for rectal mucosal bleeding with increasing risk of bleeding with higher volumes and higher doses to the rectum.

Both a high dose to the target and an adequate shielding of the organs at risk is therefore important for the outcome of radiation therapy of the prostate. This requires, first of all, an accurate and consistent delineation of both the target areas and organs at risk, especially in multicenter trials.

Several authors assessed the interobserver variation and intermodality variation of the delineated target volume (13-16). The main regions of uncertainty are the apex and posterior aspect of the prostate (13-15). The posterior border of the target volume is likely to influence the amount of irradiated rectum, and a systematic difference in outlining of the prostate will therefore result in a different complication rate. Furthermore, if the complication rate is estimated from the calculated dose to the rectum, and the relative volume of the rectum receiving that dose or more, an accurate and reproducible delineation of the rectum is important as well.

In 1997, a Dutch multi-institutional Phase III trial (CKVO 96-10) was initiated comparing 68 and 78 Gy for localized prostate cancer. The main patient eligibility criteria were T1-4, N0, M0, PSA <60 ng/ml, and biopsy-proven adenocarcinoma of the prostate. The patients were divided into four prognostic groups dependent on the T-stage, pre-treatment PSA level, and Gleason sum, with group 1 for patients with a low T-stage, PSA, and Gleason sum, and group 4 for patients with T3b -T4 stage (TNM 1997 classification).
and any PSA and Gleason sum. The dose to the various target volumes was delivered according to the randomization and the prognostic groups (Table 2-1).
As part of a quality assurance procedure prior to the start of the trial, the delineation of the various volumes and the treatment planning of the two institutions already enrolled in the study were compared. During the trial, an additional random sample of 12 of the first 120 randomized cases was reviewed by the nontreating institution.
The purpose of this study is to detect and minimize differences in the treatment planning procedure between the two institutions.

Patients and methods

General
A pelvic computed tomography (CT) scan was generated of 22 patients with localized prostate cancer. The patients were randomly selected from a Dutch multi-institutional trial (CKVO 96-10), randomizing between a dose of 68 Gy versus 78 Gy, specified at the ICRU reference point (17). The CT scans were made with 3-5 mm adjacent slices. The CT matrix size was 512 x 512 for patients from institution A and 256 x 256 for patients from institution B. No contrast enhancement was used. The gross tumor volumes (GTVs) and

Table 2.1: Prognostic group, GTV, and dose to the different PTVs for each patient. For irradiation to a dose of 68 Gy, only PTV1 and / or PTV2 are irradiated.

<table>
<thead>
<tr>
<th>Patient #</th>
<th>group</th>
<th>GTV 1</th>
<th>GTV 2</th>
<th>PTV 1</th>
<th>PTV 2</th>
<th>PTV 3</th>
<th>PTV 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,6</td>
<td>1</td>
<td>yes</td>
<td>no</td>
<td>68 Gy</td>
<td>-</td>
<td>10 Gy</td>
<td>-</td>
</tr>
<tr>
<td>2,5,7,10</td>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>18 Gy</td>
<td>50 Gy</td>
<td>10 Gy</td>
<td>-</td>
</tr>
<tr>
<td>3,8</td>
<td>3</td>
<td>yes</td>
<td>yes</td>
<td>-</td>
<td>68 Gy</td>
<td>10 Gy</td>
<td>-</td>
</tr>
<tr>
<td>4,9</td>
<td>4</td>
<td>no</td>
<td>yes</td>
<td>-</td>
<td>68 Gy</td>
<td>-</td>
<td>10 Gy</td>
</tr>
</tbody>
</table>

GTV 1 = prostate
GTV 2 = prostate and seminal vesicles
PTV 1 = GTV 1 + 10 mm expansion
PTV 2 = GTV 2 + 10 mm expansion
PTV 3 = GTV 1 + 0 mm expansion posterior and + 5 mm elsewhere
PTV 4 = GTV 2 + 0 mm expansion posterior and + 5 mm elsewhere

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normal structures were delineated on the CT scan by each institution independently. The GTV1 was defined as the prostate, GTV2 was defined as the prostate and seminal vesicles. The rectum, including filling, was delineated from the most caudal slice where the tuber ischiadicum was still visible to the most cranial slice, where the rectum was still adjacent to the sacrum, or at the most caudal level of the sacroiliac joints. The bladder was delineated without specific instructions. The femur was delineated from the femoral head down to the level of the tuber ischiadicum.

Methods of three-dimensional (3D) expansion

The planning target volumes (PTVs) were generated by 3D expansion of the GTV in each institution independently (Table 2-1). The methods of expansion of the GTVs were fully 3D in both institutions, but differed between the two institutions in the methodology of the expansion. In institution A, a triangulated surface was generated from the GTV contours. At a distance of 10 mm from the center of each triangle, and perpendicular to its surface, a new point was generated; subsequently, the PTV was generated from these points. In institution B, a 3D-coverage matrix was determined over the delineated GTV (18). The PTV was generated by placing spheres with a radius of 10 mm at the centers of all voxels. Theoretically, the expansion method of institution B is better than the method of institution A; especially at sharp edges of the GTV, the margin of institution A will be too small. Therefore, a new algorithm in institution A, similar to the algorithm applied in institution B, was used additionally for expansion of the GTVs of institution A.

The volume increases from GTV to PTV depends greatly on the shape and size of the GTV. A measure for the shape of the GTV is the ratio of the volume and the surface. For comparison of the shape of the GTVs, this ratio was assessed. For the volume, the radius of a sphere with the same volume was calculated. Likewise for the surface, the radius of a sphere with the same surface was calculated. These two radii were then expressed as a ratio called the equivalent sphere volume / surface ratio (i.e., nominal length). This ratio ranges between 0 and 1, with 1 for a perfect sphere.
**Treatment planning**

For each patient, individual isocentric three-field (AP and two lateral), conformal treatment plans were generated with a dose of 78 Gy (Table 2-1) at the ICRU reference point (17). In institution A, this was performed utilizing the U-Mplan (University of Michigan) planning system with the data from an EOS SL20 (Elekta Oncology Systems), 8- and 18-MV dual-energy linear accelerators and a 1-cm wide multileaf collimator. In institution B, this was performed with the Cadplan (Varian) planning system with the data of a Racetrack Microtron, 25-MV photon beam, and a 1.25-cm wide multileaf collimator.

**Dose and delineation comparison**

Twelve of the 22 patients were critically reviewed for compliance with the trial protocol. The remaining 10 cases were exchanged between the two institutions. The mean age of these 10 patients was 74 years (range 70-78), the T-stage ranged from T1c to T3. The mean PSA level was 11 ng/ml (range 5.6-27.4). No hormonal treatment was given to any of the patients prior to treatment. The GTVs and PTVs were determined in the other institution again and a treatment plan was generated for both PTVs, resulting in three treatment plans for each case (Table 2-2). In summary, for patients 1-5, a treatment plan by institution A on the PTV of institution A, a treatment plan by institution B on the PTV of institution B, and a third treatment plan by institution A on the PTV of institution B was generated (Table 2-2). For patients 6-10, institution A and B are reversed (Table 2-2).

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Technique of institution A (cm³)</th>
<th>Technique of institution B (cm³)</th>
<th>Difference (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>320</td>
<td>331</td>
<td>28</td>
</tr>
<tr>
<td>1-5</td>
<td>302</td>
<td>388</td>
<td>18</td>
</tr>
<tr>
<td>6-10</td>
<td>340</td>
<td>360</td>
<td>28</td>
</tr>
<tr>
<td>1-5</td>
<td></td>
<td>418</td>
<td></td>
</tr>
<tr>
<td>6-10</td>
<td></td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

Table 2-2: Mean treated volume ≥ 95% for the two techniques and the two PTVs. For example: the mean treated volume ≥ 95% for the technique of institution B to irradiate the PTVs of institution A is 331 cm³ and only available for patients 1-5. The mean difference due to differences in PTV is ((28 + 34)/2) = 31 cm³, the mean difference due to differences in technique is ((28 + 44)/2) = 36 cm³.
The delineated normal structures, the GTVs, and the PTVs were compared. The intersection (i.e., the largest volume common to two volumes) (Fig. 2-1) and the union (i.e., the smallest volume encompassing two volumes) (Fig. 2-1) were calculated. The surfaces of the GTVs and PTVs were scanned using polar coordinates \( \phi \) (angle of the vector in the coronal plane, for each 7.2 degrees, from 0 to 360 degrees) and \( \theta \) (angle of the vector out of the coronal plane, for each 3.6 degrees, from -90 to 90 degrees). This method was described earlier by Rasch et al. (14) and Remeijer et al. (19). For each patient and delineating institution, the distance in a specific direction \((\phi, \theta)\) was measured from the average center of gravity of the prostate to the edge of the delineated prostate and plotted on a two-dimensional (2D) map (Fig. 2-2a). The systematic institutional difference was defined as the average difference in distance from the center of gravity of the prostate to the edge of the GTV and PTV as delineated in institution A and the edge delineated in institution B. The standard deviation (SD) of this difference was calculated for each \( \phi \) and \( \theta \). The dose-volume histograms (DVHs) of the PTVs and normal structures were generated for each treatment plan and compared.
Results

Prostate

The volume of the prostate (GTV1), and the volume of the prostate and seminal vesicles (GTV2) were about equal in both institutions (Table 2-1, 2-3). The average ratio was 1.01 and 1.03 for GTV1 and GTV2, respectively. No significant statistical differences from 1 could be demonstrated. The mean equivalent sphere volume/surface ratio was 0.89 and 0.85 for the GTV1 of institution A and institution B, respectively, and 0.78 and 0.76 for the GTV2s (i.e., the shape of the GTVs was similar in the two institutions).

The planning target volumes (PTV1 - 3) (Table 2-3) were smaller in institution A than in institution B. The ratio was 0.87, 0.93, and 0.85 for PTV1, PTV2, and PTV3, respectively. All were significantly different from 1 (p=0.003, p=0.01, p=0.0003). Because a PTV4 was drawn only for two patients, this volume was not further analyzed.

For comparison of the 10-mm expansion routines in the institutions, the GTV2 as delineated by institution B was expanded by institution A using the "old" expansion routine as described in the Patients and Methods section. The mean ratio of these PTVs (expansion of institution A/ expansion of institution B) was 0.88 (SD 0.08, p=0.005). The "new" expansion algorithm of institution A was more comparable with the expansion algorithm of institution B. The ratio of the expanded GTVs was 0.98 (SD 0.02).

3D comparison

The mean 3D GTV1 (prostate only) institutional difference (institution A - institution B) (8 patients) (Table 2-1) was -4 mm (SD 5 mm) (Fig. 2-2b) at the base of the seminal vesicles (θ=-30 degrees and φ=0-120 degrees) and -3 mm (SD 4 mm) at the apex (θ=10 degrees and φ=300 degrees) (Fig. 2-2b) (Table 2-4). When comparing the GTV2 (prostate and seminal vesicles) (8 patients) (Table 2-1), the differences were similar (Fig. 2-2c) (Table 2-4). The mean PTV1 (prostate + 10 mm) institutional difference was largest at the base of the seminal vesicles, -8 mm (SD 6 mm) (Fig. 2-2d) (Table 2-4). At the apex, the difference was comparable to the difference at the GTVs, -3 mm (SD 3 mm) (Fig.2-2d) (Table 2-4). The mean PTV2 and PTV3 differences were similar to the PTV1 difference (Fig.2-2e) (Table 2-4).
The mean difference of the GTV2 + 10 mm (PTV2) as expanded by institution A, and the same GTV2 as expanded with 10 mm by institution B (8 patients) is demonstrated in Fig. 2-2f. The largest mean difference was 4 mm (SD 5 mm), located at the junction of the seminal vesicles.

Figure 2-2: Map of the prostate surface in polar coordinates. The various regions of interest are indicated (upper left). The mean difference in delineation of GTV1 (institution A – institution B) (upper right) and GTV2 (mid left). The mean difference in PTV1 (mid right) and PTV2 (lower left). The mean difference in distance to the surface from the GTV2 as expanded with 10 mm by institution A minus the same GTV2 as expanded with 10 mm by institution B is shown in the lower right graph.
**Organs at risk**

The mean rectal volume for the 10 patients was 112 cm³ for institution A and 125 cm³ for institution B. This volume difference was located mainly superior-anterior (i.e., at the sigmoid). The mean ratio between the rectal volume in institution A and the rectal volume in institution B was 0.88 (SD 0.18) which differs significantly \((p=0.03)\) from 1. The ratio of the union and intersection for the rectum was 1.42 (SD 0.22). The mean bladder volume was 233 cm³ for institution A and 227 cm³ for institution B. The ratio between the bladder volume in institution A and the bladder volume in institution B was 1.03 (SD 0.04, non significant (n.s.)). The ratio of the union and intersection for the bladder was 1.11 (SD 0.04). The delineated hipbones differed little.

**Dose**

The trial prescription for the dose homogeneity within the PTV was as follows: "99% or more of the PTV is to be irradiated to 95% or more of the prescribed dose, where the prescribed dose is defined by the dose at the ICRU reference point (17). The maximum dose within the PTV is 107% ". Both institutions fulfilled this criterion for irradiation of their own PTVs. The mean dose to the high-dose PTV (prescribed dose 78 Gy) was between 77.4 and 77.7 Gy for both institutions.

In all cases, institution B, using the beams designed for their own PTV, would have irradiated the PTVs of institution A according to the trial prescription. This is as expected, because their own PTVs were larger than the PTVs of institution A. On the other hand, although the technique was designed for their own (smaller) PTVs, institution A would have irradiated the PTVs of institution B according to the trial prescription in 8 of 10 cases.

Table 2-3: Comparison of GTV and PTV for the two institutions. (* n.s. = non-significant).

<table>
<thead>
<tr>
<th></th>
<th>GTV 1</th>
<th>GTV 2</th>
<th>PTV 1</th>
<th>PTV 2</th>
<th>PTV 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Mean volume of institution A</td>
<td>79 cm³</td>
<td>110 cm³</td>
<td>218 cm³</td>
<td>299 cm³</td>
<td>118 cm³</td>
</tr>
<tr>
<td>Mean volume of institution B</td>
<td>78 cm³</td>
<td>107 cm³</td>
<td>250 cm³</td>
<td>323 cm³</td>
<td>138 cm³</td>
</tr>
<tr>
<td>Mean volume ratio (A/B) (SD)</td>
<td>1.01 (0.09)</td>
<td>1.03 (0.10)</td>
<td>0.87 (0.10)</td>
<td>0.93 (0.09)</td>
<td>0.85 (0.09)</td>
</tr>
<tr>
<td>Union / intersection mean (SD)</td>
<td>n.s.*</td>
<td>n.s.*</td>
<td>p = 0.003</td>
<td>p = 0.01</td>
<td>p = 0.0003</td>
</tr>
<tr>
<td>Union / intersection mean (SD)</td>
<td>1.28 (0.08)</td>
<td>1.28 (0.06)</td>
<td>1.26 (0.11)</td>
<td>1.22 (0.07)</td>
<td>1.32 (0.10)</td>
</tr>
</tbody>
</table>
The mean treated volume ≥ 95% was 320 cm$^3$ (patients 1-5: 302 cm$^3$, patients 6-10: 340 cm$^3$) (Table 2-2) for institution A on the PTVs of institution A. and 388 cm$^3$ (patients 1-5: 360 cm$^3$, patients 6-10: 418 cm$^3$) (Table 2-2) for institution B on the PTVs of institution B. The mean treated volume (≥ 95%) outside the PTV (mean volume ≥ 95% - mean volume of high dose PTV) was (320-135) = 185 cm$^3$ for institution A and (388-159) = 229 cm$^3$ for institution B.

The treated volume ≥ 95% for institution A on the PTVs of institution B (patients 6-10) was 384 cm$^3$ (Table 2-2) and for institution B on the PTVs of institution A, 331 cm$^3$ (patients 1-5) (Table 2-2). In other words, the mean effect of the PTV differences on the treated volume ≥ 95% was ((384-340)+(360-331))/2 = 36 cm$^3$ (= 10%) (Table 2-2). The effect of the different techniques on the mean treated volume ≥ 95% was ((331-302)+(418-384))/2 = 31 cm$^3$ (= 9%) (Table 2-2).

The dose to the rectum was restricted in the trial protocol; no more than 40% of the rectal volume should receive a dose greater or equal to 74 Gy. All techniques fulfilled this criterion. The mean rectal volume receiving ≥ 74 Gy was 21 cm$^3$ (Fig. 2-3, Table 2-5) for the technique of institution A on the PTVs of institution A and the rectum delineation of institution A. This high-dose volume was nearly the same when the rectum delineation of institution B was used. For the technique of institution B on the PTVs of institution B, the high-dose volumes were larger: 27.5 cm$^3$ and 26 cm$^3$ for the rectum delineation of institution A and B, respectively.

Table 2-4: Mean institutional 3D differences. Difference in distance from the center of gravity of the prostate between institution A and B.

<table>
<thead>
<tr>
<th>Apex mean difference (SD) (mm)</th>
<th>Seminal vesicles mean difference (SD) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTV 1 -2 (3)</td>
<td>-3 (5)</td>
</tr>
<tr>
<td>GTV 2 -2 (3)</td>
<td>-3 (4)</td>
</tr>
<tr>
<td>PTV 1 -3 (3)</td>
<td>-8 (6)</td>
</tr>
<tr>
<td>PTV 2 -3 (3)</td>
<td>-6 (4)</td>
</tr>
<tr>
<td>PTV 3 -2 (2)</td>
<td>-6 (5)</td>
</tr>
</tbody>
</table>
Table 2-5: Comparison of the rectum volume receiving ≥ 74 Gy for the technique of institutions A and B and for the rectum definitions of institutions A and B.

<table>
<thead>
<tr>
<th>Rectum definition</th>
<th>Technique A</th>
<th>Technique B</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21 cm³</td>
<td>26 cm³</td>
<td>5 cm³</td>
</tr>
<tr>
<td>B</td>
<td>22 cm³</td>
<td>27.5 cm³</td>
<td>5.5 cm³</td>
</tr>
<tr>
<td>Difference</td>
<td>-1 cm³</td>
<td>-1.5 cm³</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2-3: Graphical presentation of the dose to the rectum as calculated for two techniques (institutions A and B) and two definitions of the rectum (rectum 1 and 2).

Quality control during the trial

A random selection of 12 cases of the first 120 patients was critically reviewed by the nontreating institution. In 3 cases, the reviewing institution considered the GTV more than 5 mm too small at the apex region. In 1 case, the treating institution thought this was correct, in retrospect. In 6 cases, the rectum was either delineated too small or too large. The differences all appeared at the top end of the rectum towards the sigmoid. In 1 case, a different delineation of the rectum would have lead to a calculated dose of ≥ 74 Gy to 47% of the rectum. This is above the acceptable level according to
the trial protocol, and would have led to a reduction in the number of fractions and dose to the PTV.

Discussion

The main differences between the institutions were the PTV size, the rectum delineation, and the treated volume ≥ 95% of the prescribed dose. The GTVs did not differ much; the main areas of differences in delineating the prostate occurred at the apex and the base of the seminal vesicles. These areas correspond with the areas of uncertainty found in the literature (14-16). The magnitude of these differences is comparable to the interobserver variation between observers in one institution (14).

Finding a mean PTV volume ratio of 0.9 was unexpected. Because comparison of the two expansion modules produced a similar PTV ratio (0.88), and the GTV equivalent sphere volume/surface ratio was similar for the two institutions, the discrepancy could not be explained by differences in shape of the GTV. By visual comparison of the PTVs, this proved to be true; in case of a considerable difference of GTV contours between two adjacent slices, the 3D margin generated by institution A was smaller than the prescribed 10 mm. The largest mean difference was located at a clinically important area (i.e., toward the junction with the rectal wall). This location is the same as described earlier by Stroom et al. (21) when comparing a 2D-expansion algorithm with a 3D algorithm. Although the expansion routines in the current study were 3D from the start, the new, improved expansion algorithm of institution A proved to overcome the differences and will be used in the future at institution A.

The mean treated volume ≥ 95% was smaller for institution A than for institution B (320 cm³ vs. 388 cm³) (Table 2-2). This difference can be attributed to difference in the PTV and differences in the technique. The difference in PTV was responsible for 36 cm³. This effect is fully due to the differences in expansion routines. The difference due to the variations in technique (31 cm³) is of a similar magnitude (Table 2-2). Investigation of the exact cause of this effect is beyond the scope of this study; a possible explanation could be the larger leaf dimension (1.25 cm vs. 1.0 cm) in institution B.

The ratio of the delineated rectum volumes (including filling) was 0.88. The relative DVH of the rectum (volume in a dose bin/total delineated rectum volume) has a similar ratio. The delineation of the rectum (including filling) therefore greatly influences the relative DVH of the rectum. Because the
rectal complication rate depends both on the volume and the dose (3, 8-10, 20), the results of this study stress the importance of clinically relevant and reproducible definitions of rectum delineation for an accurate complication estimation. As a result of this study, the delineating instructions of the rectum are adapted: “the rectum is delineated from the level of the tuberosities till the level of the inferior border of the sacroiliac joints, or when the rectum is no longer adjacent to the sacrum”. A new structure, sigmoid, is delineated for that part of the (recto)sigmoid adjacent to the delineated rectum till the lower border of the sacroiliac joint and the anterior border of the femoral head. This structure is used for evaluation of the trial results only. No dose restrictions apply to the sigmoid. The dose/volume criterion for the rectum (no more than 40% of the rectal volume receives 74 Gy or more) is based on the new rectum definition.

**Conclusion**

Differences in delineation of the prostate between observers of different institutions are small, and are comparable to the differences between observers in the same institution. The different expansion routines in the planning systems lead to considerably different PTVs. The differences in expansion are mainly located near the base of the seminal vesicles and the base of the bladder, and lead to a 10% difference in treated volume. A similar difference in treated volume is caused by differences in technique. Differences in delineation of the rectum greatly influenced the calculated risk of rectal complications. Applying a stricter definition for delineation of organs at risk will therefore improve the reliability of the trial results.

**Reference list**


Comparison of prostate irradiation


