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Endorectal balloon

The effect of endorectal balloon on anorectal dose during postoperative volumetric arc radiotherapy of prostate cancer

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ABSTRACT

Purpose: To evaluate the impact of endorectal balloon (ERB) on anorectal dose during postoperative VMAT of prostate cancer.

Methods: In ten patients referred for salvage radiotherapy CTs were obtained without ERB and with air-filled ERB of 50 ml and 100 ml. CTs were repeated weekly (4–6 control CTs) and registered to the respective planning CT. For each planning CT, a VMAT plan was made with defined anorectal dose constraints and propagated on the respective control CTs. The dose volumes V40 Gy, V60 Gy and V65 Gy of the rectal and anal wall (Rwall and Awall, respectively) and the ERB position were obtained from each plan.

Results: In plans with ERB, the mean Rwall dose volumes V40 Gy, V60 Gy and V65 Gy were higher by 8%, 5% and 2% (ERB 50 ml) and 2%, 3% and 3% (ERB 100 ml) in comparison to plans without ERB. The respective Awall dose volume differences were 2%, 0%, −1% (ERB 50 ml), and −3%, −2%, −2% (ERB 100 ml). The dose volume variability of the Rwall was comparable with and without ERB, but was slightly reduced by ERB for the Awall. The mean ERB position variability was >2 mm in anterior–posterior and inferior–superior directions.

Conclusion: The use of ERB during post-operative VMAT has no advantages for anorectal dose.

It is well established that the use of air-filled endorectal balloons (ERB) results in reduced anorectal dose during definitive radiotherapy (RT) of the prostate [1–3]. In addition, the ERB reduces the intra-fractional and possibly also the inter-fractional prostate motion, thus stabilizing dose distribution and allowing reduction of PTV margins and dose escalation to the prostate [4–6]. On the other hand, the reproducibility of the ERB position is limited and ERB displacements have been found to influence the dose coverage of the prostate [7,8].

In the case of post-prostatectomy RT the benefit of ERB is much less clear, because in the latter situation the anatomical changes induced by ERB and the variability of ERB position might be different due to the missing counterfort of the prostate. The inter-fractional geometric variation of the postoperative prostate bed and the anterior rectal wall during treatment without ERB has been investigated with different matching procedures in a variety of studies, and uncertainties up to 1 cm were reported [9–13]. Only limited data exist if the use of ERB can reduce this uncertainty. Jameson et al. [14] demonstrated improved geometric reproducibility of the CTV, bladder and rectum by use of ERB in the post-operative situation, but this did not translate into improved dosimetric stability to the rectum. The impact of ERB on anorectal dose in the postoperative setting has so far been investigated only in one study. Smeenk and colleagues [15] performed comparative planning with and without ERB at one time point before treatment and the use of ERB resulted in significantly reduced anal wall (Awall) and to a lesser degree reduced rectal wall (Rwall) doses.

Here we present the first prospective clinical study of anorectal dose analysis with and without ERB in patients treated with post-prostatectomy volumetric modulated arc radiotherapy (VMAT). All patients had weekly control CTs with and without ERB, and in case of ERB, 50 ml and 100 ml ERB volumes were compared. The aim of this study was to assess the dosimetric benefit of ERB over the complete treatment course.

Material and methods

This prospective study was approved by the local ethics committee and the institutional review board. 10 Patients with biochemical recurrence after prostatectomy and referred for salvage RT between 2008 and 2010 were included. For each patient 3 planning CTs were acquired in supine position (Siemens Definition AS,

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2 mm slice thickness, 120 kV): without ERB, with ERB volume 50 ml, and with ERB volume 100 ml (further denoted as No ERB, ERB50 and ERB100). Only patients who seemed to be anatomically suited for the use of ERB were included, i.e. in case the balloon visibly shifted the rectum unfavorably into the prostate bed, the patient was excluded from study participation. The ERB (Rectal Pro 65 mm, QLRAD B.V., Dalfsen, The Netherlands) was inflated, pulled back towards the anal canal and fixed by an individually defined stopper. All patients were treated with ERB50, obtaining a total dose of 66 Gy in 33 fractions. During radiotherapy, sets of 3 follow-up CTs were acquired weekly immediately after the treatment fraction (further denoted as control CTs), with varying sequence of either No ERB, ERB50, ERB100 or ERB100, ERB50, No ERB).

All CTs were transferred to the planning system (Eclipse 11, Varian Medical Systems, Palo Alto, USA). The control CTs were manually registered to the corresponding planning CT by means of translational shifts based on bony structures close to the prostate bed. Thus, the registration was consistent to the daily patient positioning correction before irradiation, which was done by means of daily orthogonal kV-images and weekly cone-beam-CT (CBCT).

Delineation of structures

The CTV was contoured on the planning (reference) CTs and adapted to the different anatomy with and without ERB. It was based on localization of the prostate on presurgery MRI. The CTV usually included the urethra-vesical anastomosis, the bladder neck and the original site of the base of the seminal vesicles. In case of involvement of the seminal vesicles the original position and/or the remnants were included. The borders were caudally the apex, laterally the neurovascular bundles and anteriorly the anastomosis. To account for microscopic extension the CTV was expanded by 5 mm in all directions. For creation of the PTV the CTV was expanded 1 cm anteriorly and laterally and 0.5–0.8 cm towards the rectum. On CTs with ERB the anal canal was contoured from the anal verge to the slice below the lowest slice with a visible balloon lumen. In case of No ERB, the same length and cranial border of anal canal was applied for the individual patient. The Awall was defined as the difference between the outer contour and inner contour of the anal canal. The rectum was contoured from the anal canal to the rectosigmoid flexure and the Rwall was defined as difference between outer and inner contour of the rectum. For ERB delineation, the window contrast was adjusted that the Rwall around the ERB was visible, leaving air and the balloon wall as black areas on the CT slices (upper HU limit 200, lower HU limit -400). Elliptic ERB contours were then fitted into these areas. Thus, the ellipsoidal shape of the ERB could be determined by the craniocaudal length and the maximal extension in lateral/AP directions.

Plan calculation and determination of dose volumes

For each patient, 3 plans (No ERB, ERB50 and ERB100) were calculated on the appropriate planning CTs (reference plans) using a 6 MV-VMAT technique (Eclipse, AAA11.0.31, Varian Medical Systems, Palo Alto, USA). The dose distribution was optimized with regard to the PTV (99% of the PTV covered by the 95% isodose, median PTV dose 100%, dose maximum < 107%) and the rectum/anus (dose maximum < 66 Gy, V40 Gy < 30%, posterior rectal/anal wall < 22 Gy). The treatment plans were then copied to the registered control CTs and the corresponding dose distribution was calculated (control plans).

Rectal and anal wall relative dose volumes (in % of the absolute contour volume) exposed to >40 Gy, >60 Gy and >65 Gy (V40, V60 and V65) were obtained from the corresponding dose volume histogram (DVH). The mean and standard deviation (SD) of V40, V60 and V65 were calculated for each patient from the respective plans (reference plan and control plans) for the 3 series (No ERB, ERB50 and ERB100). The absolute difference (in %) of the mean V40, V60 and V65 between ERB50 vs. No ERB and ERB100 vs No ERB plans was calculated for each patient and denoted as ΔV40, ΔV60 and ΔV65. Finally, the absolute differences (in %) of V40, V60 and V65 between the control plans and their reference plan were calculated for the 3 conditions (No ERB, ERB50, ERB100) and denoted as dV40, dV60 and dV65.

Determination of ERB shifts

The ERB position was determined as the ERB centre of mass relative to the isocentre, defined by the lateral, anterior–posterior and inferior–superior distance. Changes of ERB position were measured relative to the planning CT as right-left (RL), anterior–posterior (AP) and inferior–superior (IS) shifts. Positive shifts were defined towards left, posterior and cranial, respectively. For each patient, the mean and SD of ERB shifts over all control CTs were calculated (intra-patient ERB shift and variability) both for ERB50 and ERB100. To verify whether weekly assessments are representative we additionally determined the daily inter-fraction ERB50 shifts during RT from kV-imaging (planar orthogonal setup fields or cone-beam-CT) for two patients and the results were compared to the weekly assessments by control CTs. The influence of ERB shifts on dose volume was estimated by the correlation between the single ERB shifts and the associated dose volume differences dV40, dV60 and dV65.

Statistical analysis

From the individual mean values (dose volumes and ERB shifts) the group mean (mean of all individual means) and group SD (mean of all individual SD) were calculated. Additionally, the SD of these group values was calculated as a measure of inter-patient variability.

Group means and group SD were compared by a two-sided Students t-test between ERB50 and ERB100 (both versus No ERB). Group mean and SD of ERB shifts were compared between ERB50 and ERB100 in the same way. The correlation between ERB shifts and dose-volume changes was quantified by Pearsons correlation measure. The level of significance was generally defined as $p < 0.05$.

Results

Volume of contours

The mean PTV volumes over all patients were 104 ± 15 ccm (No ERB), 106 ± 16 ccm (ERB50) and 103 ± 15 ccm (ERB100). Mean PTV volume differences for individual patients were 1 ± 20 ccm (ERB50 vs No ERB), −2 ± 20 ccm (ERB100 vs No ERB) and −3 ± 6 ccm (ERB100 vs ERB50). The mean ERB volumes over all CTs were 53 ± 3 ccm (ERB50) and 101 ± 4 ccm (ERB100). The average volumes of Rwall were 53 ± 11 ccm, 63 ± 7 ccm and 66 ± 12 ccm for the No ERB, ERB50 and ERB100 plans, with intra-patient SD of 7 ± 2 ccm for all 3 conditions. Similarly the average volumes of Awall were 33 ± 7 ccm, 29 ± 8 ccm and 38 ± 4 ccm for No ERB, ERB50 and ERB100, with intra-patient SDs of 3 ± 1 ccm, 4 ± 2 ccm and 4 ± 2 ccm, respectively.

Dose volumes

The individual relative Rwall and Awall dose volumes are given in the Supplementary Tables 1 and 2. The Rwall dose volumes V40,