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Normal tissue sparing using different techniques for prostate irradiation

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ABSTRACT

Aim: The aim of this study was to investigate normal tissue sparing through dosimetric parameters of normal tissue volumes using different irradiation techniques for conventional (CFRT) and simultaneously integrated boost (SIB) schedules.
Background: Several dose-escalation studies for localized prostate cancer (PCa) have shown advanced biochemical relapse-free (bRFS) rates and also better local control for higher total doses using either CFRT or SIB schedules. Besides the most important organs-at-risk, absorbed dose reduction of other surrounding normal tissues are also preferable. In order to analyse the normal tissue sparing, dosimetric parameters of different normal tissue volumes were examined.
Materials and methods: Treatment plans for 15 high risk prostate cancer patients were created using RapidArc (RA), Sliding Window (SW) IMRT and 4-field box (3D-CRT) technique. In order to evaluate normal tissue sparing, the volume of pelvic region was divided into six normal tissue cylinders with 1 cm wall thickness, located in each other.
Results: All plans met the criteria of target coverage (V95%>95%). All techniques provided the same results for OARs except 3D-CRT for rectum and bilateral femoral heads. The values of V5, V10 and V15 increased in cases which included RapidArc technique and decreased for V20 and V30.
Conclusions: The dosimetric parameters for the cylindrical normal tissue volumes show that using RapidArc technique gives equal or slightly better normal tissue sparing and SIB provided the same normal tissue sparing as CFRT planned with RapidArc.

1. Background

Several dose-escalation studies[1–5] for localized prostate cancer (PCa) have shown advanced biochemical relapse-free (bRFS) rates and also better local control for higher total doses using either conventional (CFRT) or simultaneously integrated boost (SIB) schedules. Recently published results[6,7] show that prostate tumours have different biological properties to other tumour localizations. The real value of the α/β for prostate cancer has not been proved but the most probable value is 1.5 Gy.[7] In the past 15 years, multiple randomized dose-escalation trials[8–11] for PCa have shown improved bRFS rates for higher total doses. Recommended daily radiation doses vary among publications but 3 Gy could be the upper limit of the range in moderate hypofractionated treatment. According to our clinical protocol, CFRT involves 39 fractions in 8 weeks, which is the longest schedule in practice. However, an increasing number of papers show non-inferiority of SIB with several advantages, including convenience for patients and theoretically increased therapeutic benefit without increasing late toxicity. This treatment approach assumes a low α/β ratio for PCa with higher α/β ratio for normal surrounding tissues. The most important organs-at-risk are the bladder, rectum and bilateral femoral heads, although absorbed dose reduction of other surrounding normal tissues are also preferable. In order to analyse the normal tissue sparing, dosimetric parameters of different normal tissue volumes were examined. It is already known that intensity modulated radiotherapy (IMRT) gives significantly higher dose to normal tissues compared to three-dimensional conformal radiotherapy (3D-CRT). However, different combination of

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irradiation techniques or treatment planning systems would result in significant differences in dose to normal tissues and targets.[12,13]

2. Aim

The aim of this study was to compare different treatment techniques for CFRT and SIB in terms of normal tissue sparing.

3. Materials and methods

3.1. Target definitions and OARs

15 prostate cancer patients were selected in this study and CT scans were used for contouring and developing treatment plans. Prostate cancer patients can be divided into three risk groups according to the prognosis of the disease. This study involved patients only with high risk prostate cancer treated with external beam radiotherapy. The same contouring protocol was applied for all techniques.[14] Three planning target volumes (PTVs) were defined: PTVpelvis (pelvic lymph nodes, prostate gland and seminal vesicles), PTVpvs (prostate gland and seminal vesicles) and PTVpros (prostate gland). Rectum, bladder and bilateral femoral heads were delineated and spared as organs-at-risk.[15]

3.2. Fractionation

In case of cN0 (clinically node-negative) patients, our conventional fractionation schedule prescribes 44 Gy (PTVpelvis), 16 Gy (PTVpvs) and 18 Gy (PTVpros) in 2 Gy per day. SIB technique in 28 fractions could be an alternative for prostate irradiation and give biologically equivalent dose to the targets as our conventional fractionation schedule, using 1.5 Gy α/β ratio. Our protocol prescribes 50.4 Gy (PTVpelvis), 57.4 Gy (PTVpvs) and 70 Gy (PTVpros) total dose which means 1.8 Gy, 2.05 Gy and 2.5 Gy per day, respectively. Fractional doses were calculated with α/β ratios of 1.5 Gy for the prostate gland and seminal vesicles and 10 Gy was used for the pelvic lymph nodes. Escalated daily doses have a strong impact on the organs-at-risk,[16] so dose constraints for all OARs were calculated using 3 Gy as α/β ratio.

3.3. Treatment planning

Varian Eclipse™ TPS with AAA v11.0.31 calculation algorithm is used for TrueBeam linear accelerator with 3D-CRT, sliding window IMRT (SW IMRT) and volumetric arc therapy (RapidArc). CFRT schedule includes three separate treatment plans for every patient. By adding the dose distribution of each plan together we get the plan sum. All combinations of plans were made for all patients, which means 75 plans in total. Dosimetric analysis was made for only the plan sums to get clinically relevant information about dosimetry. Every plan sum includes the same irradiation technique for PTVpvs and PTVpros which was either 3D-CRT or SW IMRT. As PTVpelvis is always concave, only SW IMRT or RapidArc technique was used (Table 1). 10 MV photon energy was applied in the case of RapidArc and SW IMRT and 18 MV was chosen for 3D-CRT. SW IMRT technique included 7 beams equally distributed around the patient and RapidArc uses 2 full rotations.

3.4. Target volumes and indices

One of the main aims of treatment planning is to deliver the prescribed dose to target volumes as homogeneously as possible. There are several different definitions for homogeneity, although the homogeneity index (HI) defined by ICRU 83 [17] was used in this study as it is a widely known and accepted parameter. The index determines the homogeneity of the target according to three points on the DVH curve and the ideal value is zero. Van't Riet et al. [18,19] introduced the conformity number (CN) which shows the ratio of the target volume that absorbed at least 95% of the prescribed dose and the volume irradiated with at least 95% of the prescribed dose. Accordingly, the CN varies between 0 and 1.

Table 1
Irradiation techniques applied for the three different target volumes. PTVpelvis: pelvic lymph nodes, prostate gland and seminal vesicles, PTVpvs: prostate gland and seminal vesicles; PTVpros: prostate gland; RA: RapidArc; 3D-CRT: three dimensional conformal radiotherapy; SW IMRT: Sliding Window intensity-modulated radiotherapy; SIB: simultaneously integrated boost.

Plan name	Targets		
	PTVpelvis	PTVpvs	PTVpros
RA + 3D-CRT	RA	3D-CRT	3D-CRT
SW + 3D-CRT	SW IMRT	3D-CRT	3D-CRT
RA + SW	RA	SW IMRT	SW IMRT
SW	SW IMRT	SW IMRT	SW IMRT
SIB	RA	RA	RA

3.5. Normal tissue cylinders

Normal tissue is defined as all tissues without any planning target volumes. To study the dose of normal tissues, we created six normal tissue cylinders located in each other with 1 cm wall thickness. The first cylinder was created as the inner wall of the body contour and the next cylinder from the previous one towards target volumes (Fig. 1). As a consequence of the definition of these normal tissue cylinders, only the low dose region of dose distributions could be analysed with this method. Volume of a given low dose level could be different depending on the irradiation technique. Thus, not only mean dose but also volumetric parameters (V_{5Gy}, V_{10Gy}, V_{15Gy}, V_{20Gy}, V_{30Gy}) were investigated.

3.6. Statistics and analysis

DVH-based plan evaluation was done for each plan sum and all parameters were statistically analysed using GraphPadInStat v3.10. In order to compare the five plan sums, Kolmogorov-Smirnov test was performed regarding the normality of data distribution. If the sample followed normal distribution, repeated measures ANOVA was done and Tukey-Kramer multiple comparison post hoc test was chosen in case of a significant outcome of ANOVA. For not normally distributed parameters, the nonparametric Friedman test was applied and Dunn's multiple comparison post hoc test was done in case of significance. In both of the variance analysis tests and in the post hoc tests the difference was significant if p value was less than 0.05.

4. Results

4.1. Target volumes and indices

The average volumes of PTVpelvis, PTVpvs and PTVpros were 1139 cm^3, 227 cm^3 and 120 cm^3, respectively. For quantitative comparison of normal tissue sparing, plan normalizations for the targets are needed to be the same for all plans. Mean doses of targets in the four CFRT plan sums did not differ from each other significantly ($p > 0.05$) and the standard deviation among patients was negligible. Average mean doses of PTVpelvis, PTVpvs and PTVpros were 53.8 Gy, 76.4 Gy, 78.9 Gy and 54.4 Gy, 67.2 Gy, 71.6 Gy for CFRT and SIB schedules, respectively. Dose criteria for all target volumes were fulfilled since at least 95% of the targets were covered with the prescribed dose. HI of CFRT schedules showed similar results regardless of the selected technique (average 0.25) (Fig. 2).

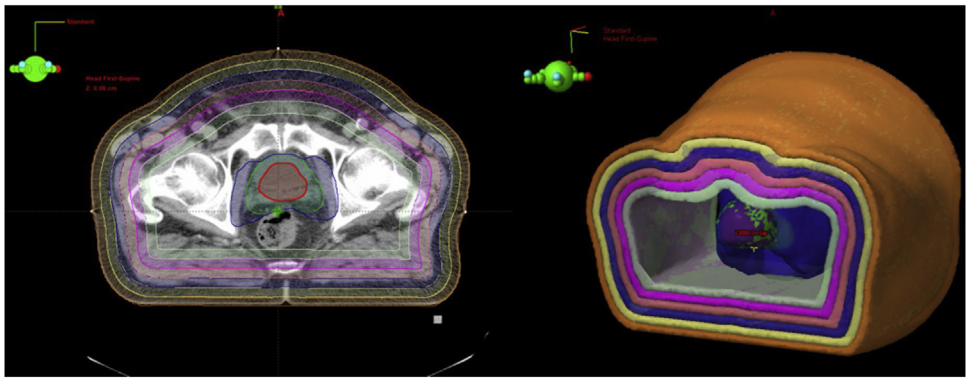

Fig. 1. Cylindrical normal tissue volumes (N1..N6) in transversal plane and in 3D model view.

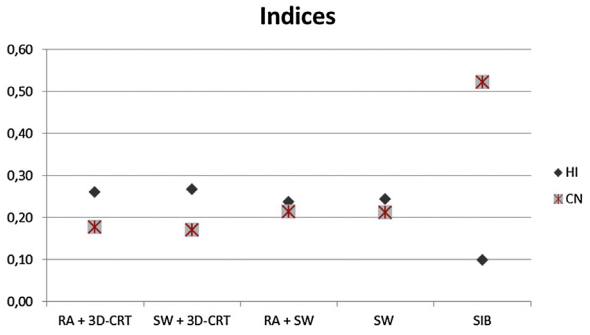

Fig. 2. Dosimetric indices of the treatment plans. HI: homogeneity index; CN: conformity index; RA: RapidArc; 3D – CRT: three dimensional conformal radiotherapy; SW: sliding window; SIB: simultaneously integrated boost.

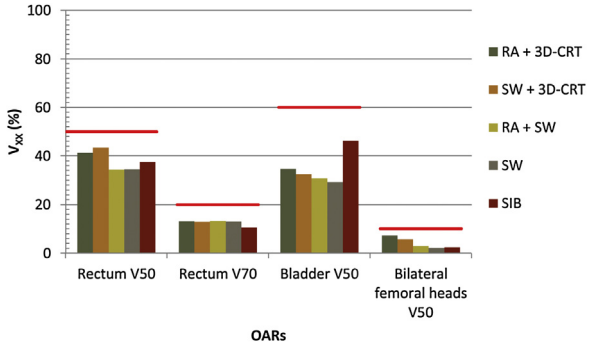

Fig. 3. Dosimetric parameters of the organs-at-risk for each plan sum. Red lines indicate the limit of the dose parameter. RA: RapidArc; 3D – CRT: three dimensional conformal radiotherapy; SW: sliding window; SIB: simultaneously integrated boost.

However, SIB schedule resulted in a significantly better homogeneity of the targets (average 0.11) compared to all CFRT plan sums ($p < 0.001$). CN of the SIB plan gave a much higher value than the CFRT plan sums with the average value of 0.52 and 0.19, respectively. The statistical analysis of CN resulted in three groups of significantly different plan sums depending on the irradiation technique of the PTVpvs and PTVpros and the fractionation schedule. CN of RA + 3D-CRT and SW+ 3D-CRT (average 0.27) were significantly different from RA + SW and SW (average 0.24) with $p < 0.01$ (Abbreviations can be found in Table 1). Statistically stronger difference was found between the CFRT plan sums and the SIB plan (average 0.11) with $p < 0.001$.

4.2. Organs-at-risk, normal tissue cylinders

Dosimetric parameters of the organs-at-risk for each plan sum can be seen in Fig. 3. All results met the criteria of both CFRT and SIB techniques. Analysis of V_{50Gy} for the rectum shows significant differences between plan sums applying 3D-CRT and SW for PTVpvs and PTVpros irradiation and there is no significant difference between techniques using the same irradiation technique for PTVpelvis irradiation. However, V_{70Gy} values for the rectum distinguish the plan sum by the fractionation schedules and so all CFRT plans had significantly higher values than the SIB plan. The V_{50Gy} of the bladder shows a significantly elevated value for SIB compared to all the other CFRT plan sums. V_{50Gy} of the bilateral femoral heads shows little but significant difference between techniques using 3D-CRT and SW for PTVpvs and PTVpros irradiation.

The average volumes for cylinders in cm^3 were: N1 = 1701, N2 = 1675, N3 = 1561, N4 = 1447, N5 = 1321, N6 = 1190. Different dosimetric parameters of normal tissue cylinders can be seen in Fig. 4 a-e and numeric results are summarized in Table 2. The lowest evaluated dose level to the cylinders was 5 Gy. V_{5Gy} showed significant difference depending on the pelvis irradiation technique in N1, N2 and N3. RA + 3D-CRT, RA + SW and SIB did not show significant difference from each other but gave significantly higher values compared to SW+ 3D-CRT and SW ($p < 0.01$) (Abbreviations can be found in Table 1). The tendency described for V_{5Gy} can also be observed at $V_{10Gy,}$ but it could also be seen in the cylinders closer to the planning target volumes. The next studied low dose level was 15 Gy (V_{15Gy}), which broke the previous trend and resulted in RA + 3D-CRT (Table 1) as significantly lower ($p < 0.001$) than SIB in N1-N4. The differences of the parameter values in a specific cylinder between plans with and without RapidArc were diminished. At the 20 Gy dose level, the plan sums with RapidArc showed significantly lower dosimetric parameters than the other three techniques ($p < 0.05$). There is no significant difference between plan sums using RapidArc. SW and SW+ 3D-CRT were statistically similar to each other as well (Abbreviations can be found in Table 1). The graph showing V30Gy also agrees with the previous results. Significant differences were found between RA + 3D-CRT and RA + SW ($p < 0.05$) (Abbreviations can be found in Table 1).

5. Conclusions

There is a wide range of irradiation techniques used for radiotherapy treatment of high risk prostate cancer patients depending on the availability and capability of the delivery equipment.[20] In this planning study, 5 different combinations of irradiation techniques were selected, which applied RapidArc or SW IMRT for the irradiation of PTVpelvis, SW IMRT or 3D-CRT for the irradiation of PTVpvs and PTVpros in case of CFRT and RapidArc in case of SIB (Abbreviations can be found in Table 1). Delineation of the target volumes and the fractionation schedule were determined according to international clinical practices.[1–5] SIB was delivered

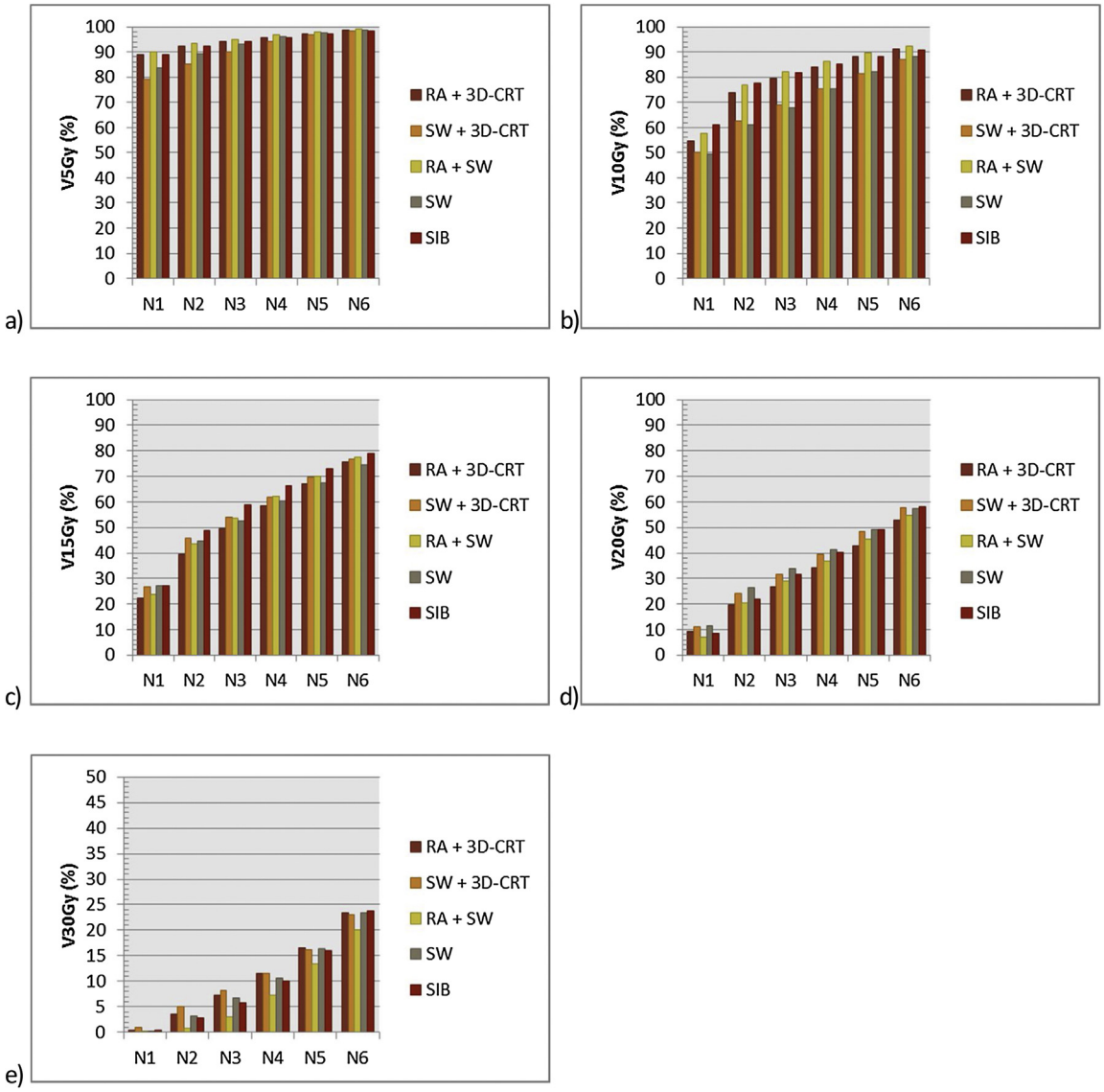

Fig. 4. Dosimetric parameters of the normal tissue cylinders (N1..N6) for each plan sum. RA: RapidArc; 3D - CRT: three dimensional conformal radiotherapy; SW: sliding window; SIB: simultaneously integrated boost.

simultaneously for the three targets and provided a mild hypofractionation schedule,[8] which was calculated by using radiobiological models.[6,7] According to Wong et al.[5] SIB is similar to CFRT in many clinical aspects; however, it often causes less serious acute toxicity if the daily fraction dose is less than 3 Gy.

As the aim of this study was to compare normal tissue sparing, target coverage had to be similar for all irradiation techniques among CFRT and SIB plans. The mean dose of targets in the same fractionation schedule did not vary significantly, which means that all the applied irradiation techniques were eligible for the treatment of high risk prostate cancer patients. This result was in agreement with the publication of Ishii et al.,[10] who found only slight superiority for RapidArc compared to 7-field and 9-field IMRT. The difference between plan sums using 3D-CRT and SW IMRT (Abbreviations can be found in Table 1) for the irradiation of PTVpvs and PTVpros was little but using 3D-CRT resulted in significantly less dose to normal tissues, but worse protection of the rectum and femoral heads.[21]

Pollack et al.[11] published statistically significant difference between CFRT and SIB plans in terms of rectum and bladder toxicity. Also, the dosimetric comparison of RapidArc and 7-field-IMRT was done by Ishii et al.[10] and resulted in similar OAR sparing for both techniques, although delivery efficiency was significantly higher for RapidArc. Yamazaki et al.[7] concluded that bRFS was comparable between the CFRT and SIB arms after a 30 month follow-up. Regarding the late toxicity reduction of the rectum, hypofractionation seemed preferable for localized prostate cancer patients, which supports the conclusion of our work.

Beside the OAR toxicity, dosimetric analysis of normal tissue cylinders is a possible tool for comparing different irradiation techniques regarding normal tissue sparing. This method provides a unique aspect for evaluation of the low dose region of the pelvic irradiation which might enhance radiation induced second primary cancer risk.[22] Evaluating the volume of specific low dose levels resulted as presumed. In case of CFRT, plan sums with RapidArc for pelvic irradiation are much more favourable and only low dose ratio under 15 Gy increases with this technique. The selected irradiation techniques resulted in specific dose distribution shapes and different low dose region depending on the number and direction of the beams. All plan sums with SW IMRT or 3D-CRT resulted in high dose regions along the beam directions, which obviously raised all V_{xx} parameters above 15 Gy (Abbreviations can be found in Table 1).

Table 2
The percentage average volumes of V5Gy, V10Gy, V15Gy, V20Gy, V30Gy for normal tissue cylinders. If the sample followed normal distribution, repeated measures ANOVA was done and Tukey-Kramer multiple comparison post hoc test was chosen in case of significant outcome of ANOVA. For not normally distributed parameters, nonparametric Friedman test was applied and Dunn's multiple comparison post hoc test was done in case of significance. In both of the variance analysis tests and in the post hoc tests the difference was significant if p value was less than 0.05. RA: RapidArc; 3D - CRT: three dimensional conformal radiotherapy; SW: sliding window; SIB: simultaneously integrated boost.

	V5						V10					
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
RA + 3D-CRT	88.8	92.3	94.0	95.8	97.4	98.6	54.5	73.8	79.6	84.1	88.0	91.3
SW + 3D-CRT	79.1	85.1	90.0	94.2	96.8	98.3	50.3	62.5	68.8	75.4	81.4	87.0
RA + SW	90.1	93.3	95.1	96.8	98.2	99.1	57.8	76.9	82.2	86.2	89.6	92.3
SW	83.5	89.2	93.2	96.0	97.7	98.7	49.3	61.1	67.8	75.3	82.3	88.2
SIB	89.1	92.3	94.1	95.8	97.2	98.2	61.0	77.5	81.7	85.1	88.1	90.8
ANOVA p value	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0.0031	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
RA + 3D-CRT vs SW + 3D-CRT	p < 0,001	p < 0,001	p < 0,001	p < 0,01	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001
RA + 3D-CRT vs RA + SW	n.s.	n.s.	n.s.	n.s.	p < 0,05	n.s.	p < 0,05	p < 0,05	n.s.	n.s.	n.s.	n.s.
RA + 3D-CRT vs SW	n.s.	p < 0,01	n.s.	n.s.	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,05	p < 0,001
RA + 3D-CRT vs SIB	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	p < 0,001	p < 0,01	n.s.	n.s.	n.s.	n.s.
SW + 3D-CRT vs RA + SW	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,05	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001
SW + 3D-CRT vs SW	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
SW + 3D-CRT vs SIB	p < 0,001	p < 0,001	p < 0,001	p < 0,01	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001
RA + SW vs SW	p < 0,001	p < 0,001	p < 0,05	n.s.	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001
RA + SW vs SIB	n.s.	n.s.	n.s.	n.s.	p < 0,01	p < 0,01	p < 0,05	n.s.	n.s.	n.s.	n.s.	n.s.
SW vs SIB	p < 0,01	p < 0,01	n.s.	n.s.	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,05	p < 0,01

[10pt]

	V15						V20					
	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
RA + 3D-CRT	22.4	39.3	49.4	58.4	67.2	75.7	9.4	19.7	26.7	34.1	43.0	52.9
SW + 3D-CRT	26.9	45.6	53.8	61.9	69.6	76.6	10.9	24.0	31.4	39.4	48.3	57.8
RA + SW	23.9	43.5	53.6	62.1	70.1	77.6	6.9	20.6	29.2	36.9	45.3	54.6
SW	27.2	44.5	52.6	60.3	67.5	74.4	11.6	26.2	33.8	41.4	49.2	57.3
SIB	27.1	48.7	58.7	66.2	73.1	79.1	8.7	22.0	31.6	40.3	49.0	58.1
ANOVA p value	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0.0012	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0.0002
RA + 3D-CRT vs SW + 3D-CRT	p < 0,001	p < 0,001	p < 0,001	p < 0,05	n.s.	n.s.	p < 0,05	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,01
RA + 3D-CRT vs RA + SW	n.s.	p < 0,001	p < 0,01	p < 0,05	n.s.	n.s.	p < 0,001	n.s.	p < 0,01	p < 0,01	n.s.	n.s.
RA + 3D-CRT vs SW	p < 0,001	p < 0,001	p < 0,05	n.s.	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,01
RA + 3D-CRT vs SIB	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	n.s.	n.s.	p < 0,01	p < 0,001	p < 0,001	p < 0,001	p < 0,01
SW + 3D-CRT vs RA + SW	p < 0,001	n.s.	n.s.	n.s.	n.s.	n.s.	p < 0,001	p < 0,001	p < 0,05	p < 0,05	p < 0,05	n.s.
SW + 3D-CRT vs SW	n.s.	n.s.	n.s.	n.s.	n.s.	p < 0,05	n.s.	p < 0,05	p < 0,05	n.s.	n.s.	n.s.
SW + 3D-CRT vs SIB	n.s.	p < 0,05	p < 0,001	p < 0,01	p < 0,05	n.s.	p < 0,001	p < 0,05	n.s.	n.s.	n.s.	n.s.
RA + SW vs SW	p < 0,001	n.s.	n.s.	n.s.	n.s.	p < 0,01	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,01	n.s.
RA + SW vs SIB	p < 0,001	p < 0,001	p < 0,001	p < 0,01	n.s.	n.s.	p < 0,01	n.s.	p < 0,01	p < 0,001	p < 0,01	n.s.
SW vs SIB	n.s.	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,01	p < 0,001	p < 0,001	p < 0,05	n.s.	n.s.	n.s.

	V30					
	N1	N2	N3	N4	N5	N6
RA + 3D-CRT	0.5	3.5	7.3	11.5	16.6	23.3
SW + 3D-CRT	1.0	5.1	8.3	11.5	16.2	23.0
RA + SW	0.0	0.8	3.0	7.4	13.3	20.2
SW	0.3	3.1	6.7	10.7	16.4	23.4
SIB	0.3	2.8	5.8	10.1	16.0	23.8
ANOVA p value	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0.0005
RA + 3D-CRT vs SW + 3D-CRT	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
RA + 3D-CRT vs RA + SW	p < 0,01	p < 0,01	p < 0,001	p < 0,001	p < 0,001	p < 0,01
RA + 3D-CRT vs SW	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
RA + 3D-CRT vs SIB	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
SW + 3D-CRT vs RA + SW	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,001	p < 0,05
SW + 3D-CRT vs SW	p < 0,01	p < 0,05	n.s.	n.s.	n.s.	n.s.
SW + 3D-CRT vs SIB	p < 0,01	n.s.	p < 0,001	n.s.	n.s.	n.s.
RA + SW vs SW	p < 0,05	p < 0,05	p < 0,001	p < 0,05	p < 0,01	p < 0,05
RA + SW vs SIB	n.s.	p < 0,05	p < 0,001	p < 0,05	p < 0,05	p < 0,01
SW vs SIB	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

On the other hand, RapidArc resulted in virtually homogeneous low dose distribution thus raising V_{xx} parameters below 15 Gy.

Analysis of dosimetric parameters of the six normal tissue cylinders is an effective method to evaluate the low dose region inside the body depending only on the distance from the target volumes. It was found that the ratio of different low dose volumes varies depending on the irradiation technique. In terms of normal tissue sparing and dosimetric parameters, SIB was comparable with the CFRT plan sums using RapidArc. Accordingly, in case SIB is achievable, it could be more beneficial than CFRT in terms of normal tissue sparing and patient comfort as well.

A comparison of different radiotherapy techniques was performed to evaluate the radiation exposure of normal tissues, using predefined, normal tissue cylinders. V_{5Gy}, V_{10Gy} and V_{15Gy} in the low dose region increased for cases which included RapidArc technique for PTVpelvis regardless of the irradiation techniques of PTVpvs and PTVpros. V_{20Gy} for the cylindrical normal tissue volumes showed that involving RapidArc technique for PTVpelvis

gives equal or slightly better normal tissue sparing. As SIB provided the same normal tissue sparing as CFRT planned with RapidArc, it seems to be a suitable option for prostate irradiation.

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Conflict of interest

There is no conflict of interest.

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