Dosimetric comparison of fixed field dynamic IMRT and VMAT techniques in simultaneous integrated boost radiotherapy of Prostate Cancer

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Research

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Abstract

Background: As the high risk prostate cancer can be benefited from the combination of hypo-fractionated radiotherapy and pelvic conventional fraction radiotherapy, the comparison between fixed field dynamic IMRT and VMAT techniques can provide suggestion for clinical treatment.

Methods: We selected 10 patients with high risk prostate cancer who received radiotherapy at Sun Yat-sen University Cancer Center from 2013 January to 2013 December. The target including the prostate, seminal vesicle and pelvic lymph nodes. With the same prescription and optimized parameters, 9 field IMRT, single arc and double arc VMAT treatment plans were designed, which are expressed by 9F, 1ARC and 2ARC respectively. The dose distribution of the targets, organs at risk (OAR), monitor units (MUs), treatment time and gamma pass ratios of dose verification were compared.

Results: The $D_{2\%}$(69.37±0.89)Gy,$D_{50\%}$(66.92±0.63)Gy, HI(0.09±0.02) and CI(0.83±0.05) of PTV1 in 9F were slightly better than those of 1ARC which were (71.13±1.21) Gy, (68.50±0.76)Gy, (0.12±0.02), (0.74±0.07), except $D_{98\%}$, the difference were significant($p<0.05$). All dosimetric indices of PTV1 in 9F and 2ARC were close and has no significant differences ($p>0.05$). The $V_{95\%}$(99.45±0.78)% of PTV2 in 9F was slightly better than that in 1ARC (99.35±1.28)%, the difference was significant ($p<0.05$). All dosimetric indices of PTV2in 9F and 2ARC were close and the difference were no significant ($p>0.05$). The D_{mean} of bladder and the $V_{67.5Gy}$of rectum between all three plans were similarity The D_{mean} of left and right femoral in 1ARC and 2ARC were lower than that in 9F, and the difference was significant ($p<0.05$). Other dosimetric indices of OARs in 9F were lower than those in 1ARC and 2ARC, and much lower than 1ARC, the difference were significant ($p<0.05$). The mean monitor units in 1ARC and 2ARC were fewer by 70.0% and 67.2% in comparison with 9F. The treatment mean time in 1ARC and 2ARC were shorter by 81.7% and 61% in comparison with 9F. The verification pass ratios of γ(3%/3mm)were 97.8% (9F), 98.9% (1ARC) and 99.4% (2ARC) respectively, the difference were significant($p<0.05$).

Conclusion: Compared with IMRT, VMAT improved delivery efficiency noticeably. Two arcs provided comparable tumor dosimetric coverage, but performed worse in dose sparing for bladder, rectum and small bowel. IMRT plan was better than VMAT in prostate cancer simultaneous integrated boost radiotherapy.

Background

Prostate cancer is the most common noncutaneous cancer in men, with 1,212,653 case excepted in 2019 in China alone. Treatment of localized prostate cancer has been proven by clinical trial including hypo-fractionation RT dose escalation with ENI and ADT combined with RT[1–5]. With the development of radiotherapy IMRT, it has been generally used in prostate cancer. Radiation therapy related toxicities is associated with high total RT dose, short recovery time, and the volume of neighboring OAR normal tissues (rectum, bowel and bladder) ever in prostate-only RT[6, 7].In recent years, with the development of radiotherapy technology, IMRT has replaced 3-dimensional conformal radiation therapy as the most

common method of radiation therapy for prostate cancer for its conformable dose distributions which can reduce normal tissue toxicity[1, 3]. The most common method for IMRT delivery for prostate cancer involves [5–9], fixed gantry positions with computer-generated, sliding-window multi-leaf collimator positions to modulate dose to the prostate [8–10]. A more recent IMRT technique named as VMAT, involves gantry rotation around the prostate with 1 to 4 arcs while the x-ray beam is on. In VMAT technique the dose rate varies while the gantry moving around. Palma et al reported that the most favorable equivalent uniform doses and lowest doses to organs at risk were achieved with variable dose rate VMAT, which was statistically significantly better than 5-field, IMRT for rectal and femoral head endpoints and better than constant dose-rate VMAT for most bladder and rectal endpoints [11–13].Multiple groups have observed that VMAT reduces beam-on time and the radiation dose relative to 7 to 9 field IMRT.

According to NCCN guidelines, doses of 75.6 to 79.2 Gy in conventional fractions to the prostate are appropriate for patients with low-risk cancers. For patients with intermediate or high-risk disease, doses up to 81.0 Gy provide improved PSA-assessed disease control. For radical radiotherapy, patients with low-risk cancer should not receive pelvic lymph node irradiation or ADT, patients with intermediate-risk cancer may be considered for pelvic lymph node irradiation and 4 to 6month neoadjuvant/concomitant/adjuvant ADT. Patients with high-risk cancers are candidates for pelvic lymph node irradiation and the addition of neoadjuvant /concomitant/adjuvant ADT for a total of 2-3y [14].The target area of this study include prostate, seminal vesicle and pelvic lymph nodes. The studies were irradiated simultaneously, the former group is treated with conventional segmented irradiation of pelvic cavity and prostate, and then with local prostate boost, the latter group is also treated with conventional segmented irradiation. In this way, patients are treated longer and more expensive. We have to make two plans for one patient, which increase the workload of doctors and physicists. At present, several published studies have been shown that the effect of increasing single dose or reducing the total dose is similar to that of conventional fractionated irradiation and the toxicity is acceptable;Meanwhile, the second edition of NCCN guidelines for prostate cancer in 2014 also included the content of hypo-fraction radiotherapy for prostate cancer (2.4-4Gy /fraction, treatment period of 4–6 weeks). Hypo-fraction can not only shorten the treatment time and reduce the medical cost, but also improve the efficiency of medical resources. The combination of conventional segmented irradiation of pelvic cavity and the hypo-fraction radiotherapy of prostate will be more beneficial for the patients. In this paper, we compared the difference of dosimetry and treatment efficiency of the IMRT and VMAT technology which designed through Varian treatment plan system.

Methods

Patients selection and CT simulation

We selected 10 patients with high risk prostate cancer who received radiotherapy at Sun Yat-sen University Cancer Center from 2017-01-04, aged 62 ~ 78 years, median age 70 years. All of those patients didn’t go through radical prostatectomy. Planning CT scans were performed at 5 mm slice thickness

using a dedicated helical CT scanner, from the upper abdomen to 5 cm below the Ischia tuberosities after immobilization with Knee and feet support immobilization devices. CT images were transferred to the inverse TPS through network. Patients were instructed to have a comfortably full bladder and an empty rectum at CT acquisition and before each treatment. The bladder was filled to make the small intestine move downwards to reduce the volume of small intestine irradiation.

Contouring and Planning

The CTV, CTV1 was defined as the entire prostate and seminal vesicle (if involved); CTV2 included the whole prostate and seminal vesicle (if not involved). PTV1was generated by adding anisotropic 0.5 cm margin to the CTV1 apart from prosteriorly where 0.3 cm margin was added (to decrease prostate-rectal interface dose). PTV2 was a 0.7 cm anisotropic expansion from CTV2 except posteriorly (0.5–0.7 cm) depending on rectal fullness. The prescribed dose of PTV1 was 67.5Gyin 25 daily fraction and PTV2 was 47.5 Gy in 25 daily fraction. Contouring of the OAR followed the RTOG pelvic normal tissue contouring guidelines [15]. The rectum was outlined from the level of the ischial tuberosities to the rectosigmoid flexure. The whole bladder was contoured; femoral heads were delineated to the level of the ischial tuberosities. The bowel was contoured as the entire volume of peritoneal space to within 1 cm of the cranial margin of the nodal PTV. The TPS is Varian Eclipse (version 10.1); The radiotherapy equipment is Varian Trilogy linear accelerator with120 Multi-leaf Collimator, and the isocenter accuracy is 5 mm. Three intensity modulated treatment plans were designed for each case using 6MV X-ray, that were fixed field dynamic intensity modulation 9-field plan (9F), VMAT single-arc plan (1ARC) and double-arc plan (2ARC), respectively,. The maximum dose rate was set at 600MU/min. Among them, for IMRT, 9F beams were treated using a dynamic multi-leaf collimator and the radiation directions was 160°, 120°, 80°, 40°, 0°, 320°, 280°, 240°, 200°respectively; For VMAT, the 1ARC adopts a single arc of 179° to 181 °anticlockwise rotation and for the 2ARC, the first arc rotated from 179°anticlockwise to 181 °, than the second arc rotated clockwise from 181° to 179°.During the rotation of gantry, the step length of the subfield segment is 2°. There were all adopt the simultaneous integrated boost technology. The minimum allowable dose in the PTV was 93% of the prescribed dose and the maximum allowable dose in the PTV was 115% of the prescribed dose. At least 95% of the PTV received > 95% of the prescribed dose. For OAR, bladder V_{55}Gy < 30%, $V_{67.5}$Gy < 10%;Rectum V_{55}Gy < 30%, $V_{67.5}$Gy < 10%;Left and right femoral head V_{40}Gy < 5%;The small intestine D_{max} < 50 Gy. The dose constraint and optimization parameters of the three plans were the same, and the dose calculation grid size was 2.5 mm, using the AAA dose algorithm[12].

Plan quality evaluation

For the sake of convenience, the three plans were normalized after the completion, at least 95% of the PTV1 received > 95% of the prescribed dose. According to the ICRU83 report [16], the dose distribution in the target area was evaluated with the maximum dose D2%, the minimum dose D98% and the median dose D_{50}%, CI and HI are introduced to evaluate the planned dose distribution, where HI = (D_2% - D_{98}%) / D50%, CI = (TV_{RI} ×TV_{RI}) / (TV × V_{RI})(D_X% is the dose received by X% of the target volume, TV_{RI} represents the target volume within the prescription isodose volume, TV is the volume of the target area PTV, and V_{RI}

is the volume enclosed by 95% of the prescription dose line). The smaller the HI value is, the better the uniformity of the dose distribution in the target area is. The value of CI is between 0 and 1, which represents the ideal situation that the target volume coincides exactly with the treatment volume. If CI equals zero that represents a plan in which there is no overlap between the two volumes. Dose constraints were also evaluated for each plan, V_{50}Gy, V_{55}Gy, V_{60}Gy, $V_{67.5}$Gy and D_{mean} were used to evaluate rectum and bladder, V_{40}Gy and D_{mean} were used to evaluate left and right femoral head, and D_{max} and D_{mean} were used to evaluate small intestine. D_{mean} was the average dose received by OAR, and D_{max} was the maximum point dose received by OAR. Record the number of subfields, MU and effective treatment time (the time from the beginning of beam out to the end of beam out after the completion of patient positioning), and compare the results of each execution parameter of the three groups. The semiconductor three-dimensional detector array dose verification system ArcCheck was used to conduct dose verification for all plans. The maximum dose point was taken as the standard, and the dose threshold was set to 10%. The DTA and Gamma pass rates of each plan were compared under the standard of 3%/3 mm.

Statistical method

Spss19.0 software was used for statistical analysis. Shapiro-Wilk test was used to test the difference of paired data of each index of treatment plan (9F and1ARC, 9F and 2ARC). If it is in line with the normal distribution, T test was used to test the results of 9F and 1ARC, 9F and 2ARC, and Wilcoxon rank sum test was used to test the results of non normal distribution ($P < 0.05$) .The difference was statistically significant, and the data results were expressed as mean ± standard deviation ($\overline{x} \pm s$).

Result

Dosimetric comparison of target area

The mean volume of PTV (including PTV1 and PTV2) was 1153.2 ± 146.3 cm^3 (869.7 ~ 1409.0 cm^3), which was large and complex. Figure 1 shows the isodose distributions on axial images of three plans. PTV1 shown as red line, PTV2 shown as green line.PTV1 was inside PTV2. The isodose lines were displayed on an absolute dose scale, the isodose levels increased by 20 Gy ~ 70.88 Gy gradient were shown. As the dosimetric comparison of 9F with 1ARC and 2ARC is shown in Table 1: For PTV1, 9F plans were similar to 2ARC plans, there was no statistical significance ($P > 0.05$). And the $D_{98\%}$ of the three plans indices did not show any obvious difference. The $D_{2\%}$ and $D_{50\%}$ of 9F and 2ARC were closer to the prescription dose, and the HI and CI were slightly better than 1ARC, and the differences were statistically significant ($P < 0.05$). For PTV2, $V_{95\%}$ of9F was better than 1ARC, the difference was statistically significant ($P < 0.05$), but $D_{98\%}$ has no statistical significance ($P > 0.05$), 9F and 2ARC has no statistical significance ($P > 0.05$).

Dosimetric comparison of OAR

The mean results of OARs for dosimetric comparison of 9F with 1ARC and 2ARC plans are listed in Table 2. The three kinds of plans all met the clinical needs. For rectum $V_{67.5Gy}$, 9F was lower than 2arc, but the difference was not statistically significant (P > 0.05); for bladder D_{mean}, there was no statistically significant difference between the three groups (P > 0.05); for left and right femoral head D_{mean}, 1ARC and 2ARC were lower than 9F, the difference was statistically significant (P < 0.05). Other OAR parameters evaluation,the 9F plans were lower than 1ARC and 2ARC, and the difference was statistically significant compared with 1ARC (P < 0.05).

Comparison of radiotherapy efficiency and dose

Compared with 9F, 1ARC and 2ARC the monitor units (MUs) was reduced 70.0% and 67.2%, accounting for 9% and 18% of the number of subfields respectively. The average delivery time of the 9F, 1ARC, and 2ARC plans was 449.3±29 seconds, 82.2±0.8 seconds, and 175.0±0.9 seconds, respectively, reduced by 81.7% and 61%, relative to the 9F. The gamma and DTA pass rate for these plans exhibited were measured using the ArcCheck detector along with ion chamber measurements. The average pass rate was greater than 95% under the standard of 3%/3 mm, and 1ARC and 2ARC were slightly higher than 9F.The differences of the above evaluation indicators were statistically significant (p < 0.05), as shown in Table 3.

Table 1

Dosimetric comparison of 9F with 1ARC and 2ARC target areas ($\bar{x}$±s)

Parameter	9F	1ARC	t/z	p	2ARC	t/z	p
PTV1							
$D_{2\%}$/Gy	69.37 ± 0.89	71.13 ± 1.21	-4.865	0.001	69.15 ± 0.79	-0.561	0.575[a]
$D_{98\%}$/Gy	63.18 ± 0.55	63.03 ± 0.31	0.86	0.412	63.31 ± 0.20	-0.965	0.360
$D_{50\%}$/Gy	66.92 ± 0.63	68.50 ± 0.76	-6.598	0.000	67.20 ± 0.55	-1.730	0.118
HI	0.09 ± 0.02	0.12 ± 0.02	-3.406	0.008	0.09 ± 0.02	1.406	0.193
CI	0.83 ± 0.05	0.74 ± 0.07	3.866	0.004	0.79 ± 0.08	1.850	0.097
PTV2							
$V_{95\%}$/%	99.45 ± 0.78	99.35 ± 1.28	2.549	0.031	99.33 ± 0.75	0.448	0.888[a]
$D_{98\%}$/Gy	46.13 ± 0.65	45.70 ± 1.24	0.959	0.363	46.02 ± 6.14	0.442	0.669
Note: a is non-normal distribution data, and z is non-parametric test statistics							

Table 2

dosimetric comparison of 9F with 1ARC and 2ARC plans for organs at risk($\bar{x}$±s)

Parameter	9F	1ARC	t/z	p	2ARC	t/z	p
Rectum							
V_{50Gy}/%	19.78 ± 3.55	28.2 ± 1.45	-8.949	0.000	25.83 ± 0.81	-2.983	< 0.001
V_{55Gy}/%	15.02 ± 3.14	21.19 ± 1.88	-10.851	0.000	19.90 ± 1.41	-5.885	< 0.001
V_{60Gy}/%	10.48 ± 2.39	15.08 ± 2.36	-7.606	0.000	14.07 ± 1.83	-6.771	< 0.001
$V_{67.5Gy}$/%	0.99 ± 1.21	3.91 ± 2.40	-4.324	0.002	1.72 ± 1.90	-1.262	0.207[a]
D_{mean}/%	44.63 ± 1.00	47.21 ± 2.21	-4.339	0.002	45.96 ± 1.45	-3.708	0.005
Bladder							
V_{50Gy}/%	28.97 ± 5.21	45.11 ± 12.55	-2.803	0.005[a]	37.54 ± 4.96	-4.011	0.003
V_{55Gy}/%	18.56 ± 2.64	24.73 ± 1.85	-6.923	0.000	20.81 ± 3.06	-3.011	0.015
V_{60Gy}/%	13.66 ± 2.97	16.64 ± 3.34	-5.415	0.000	14.46 ± 2.76	-3.863	0.004
$V_{67.5Gy}$/%	0.88 ± 0.85	6.25 ± 2.53	-5.619	0.000	3.09 ± 1.28	-3.946	0.003
D_{mean}/Gy	48.81 ± 2.00	47.99 ± 3.72	0.908	0.387	47.55 ± 3.00	1.932	0.085
LeftFemoral Head							
V_{40Gy}/%	1.8 ± 0.74	3.39 ± 1.01	-4.235	0.002	2.49 ± 0.74	-2.697	0.024
D_{mean}/Gy	26.43 ± 3.54	23.68 ± 3.94	2.814	0.020	23.22 ± 2.81	3.980	0.003
Right Femoral Head							
V_{40Gy}/%	1.75 ± 0.74	3.37 ± 0.86	-4.313	0.002	2.44 ± 0.89	-2.531	0.032
D_{mean}/Gy	26.34 ± 3.27	22.05 ± 3.54	5.449	0.000	22.73 ± 3.58	4.739	0.001
Small Intestine							
D_{max}/Gy	44.05 ± 7.63	45.99 ± 9.07	-2.983	0.018	45.18 ± 7.79	-2.379	0.045
Note: a is non-normal distribution data, and z is non-parametric test statistics							

Table 3

comparison of 9F with 1ARC and 2ARC treatment efficiency and dose validation ($\bar{x}$±s)

Parameter	9F	1ARC	t/z	p	2ARC	t/z	p
Monitor Units	1794.8 ± 155.2	534.5 ± 76.5	37.009	< 0.001	588.3 ± 155.0	22.308	< 0.001
Segment Number	1907.5 ± 94.8	178.0 ± 0.0	57.685	< 0.001	356.0 ± 0.0	51.748	< 0.001
Treatment time /s	449.3 ± 29.0	82.2 ± 0.8	31.290	< 0.001	175.0 ± 0.9	22.747	< 0.001
DTA(3%/3mm)	96.2 ± 1.2	97.9 ± 0.5	-2.201	0.028[a]	99.1 ± 0.4	-2.201	0.028[a]
γ(3%/3mm)	97.8 ± 0.6	98.9 ± 0.4	-5.329	0.003	99.5 ± 0.3	-9.463	< 0.001
Note: a is non-normal distribution data, and z is non-parametric test statistics							

Discussion

With the volumetric modulated arc therapy widely used in clinical, there are many literatures at home and abroad comparing its difference with the intensity modulated radiation therapy, including dosimetry, treatment efficiency and dose validation pass rate. A number of previous studies have shown that in head and neck tumors and esophageal cancer, the dose distribution of VMAT is equal to or slightly better than that of IMRT, which can greatly shorten the treatment time and improve the treatment efficiency. But, the previously reported target structure is often relatively simple. The research of Guckenberger and Bortfeld shows that VMAT may not provide enough intensity modulation for more complex targets [13–14, 19–21]. In order to obtain a shorter treatment time, single arc VMAT may over sacrifice the quality of dose distribution; increasing the number of subfields or rotating arcs can improve the quality of dose distribution, However, the treatment time will increase correspondingly .

In the comparative study of radiotherapy techniques for prostate cancer, different conclusions were drawn according to the target areas of different structures and shapes. Studies only including prostate or prostate and seminal vesicle, Bedford et al [13] have shown that single-arc VMAT had better PTV coverage and less OAR exposure dose than 5-field IMRT; Boylan et al [10] have shown that single arc VMAT can better protect OAR compared with 5-field IMRT, but the PTV coverage was worse; other reports had shown that VMAT and IMRT have similar dose distribution, and with the number of fixed fields increases, the dose distribution of IMRT will gradually be equal to or even better than VMAT. Yoo et al [17] used sequential irradiation to compare the dose distribution and treatment efficiency of IMRT with single arc and double arc VMAT. The primary planning target volume contained prostate, seminal vesicles, and pelvic lymph node with a margin. The results showed that IMRT could protect bladder, rectum and small intestine, and had similar HI and CI to 2ARC, slightly better than 1ARC. For the second course plan, 2ARC

and IMRT had similar dose distribution. The results of our study aresimilar to Yoo et al: the target area coverage of IMRT is no less than or slightly better than 1ARC, similar to 2ARC; except for D_{mean} of left and right femoral head and D_{mean} of bladder, other parameters of OAR are better than 1ARC and 2ARC, and significantly better than 1ARC, which is better protection of the bladder, rectum and small intestine. In addition, those plans were normalized such that the prescription dose covered at least 95% of the PTV, after which one plan with D5 of PTV $\leq$ 110% and better OAR sparing was selected for each technique. As shown in Fig. 1, IMRT will be exposed to relatively more low fluenceregion of 20 Gy and 30 Gy, and the smoothness of dose curve will be worse. Compared with IMRT, double arc VMAT can significantly reduce the radiation dose of OAR, which is different from this result, the reason may be that the IMRT used in this study is 5F and the number of subfields is less. In general, the more field shots, the better the result.

The biggest advantage of VMAT is to greatly shorten the treatment time. This study shows that compared with IMRT, the average treatment timeof 1ARC and 2ARCshorten by 81.7% and 61%, and also reduce the number of MUs by 70.0% and 67.2% respectively, which can reduce the loss of the treatment machine. Those results are similar to the results reported by Yoo et al [17], but Quan et al [9] used AIP algorithm on Pinnacle v9.0 system to compare with VMAT and IMRT, VMAT had 30% more MUs than 8-field IMRT, but the treatment time was reduced 3 minutes. In addition, the three-dimensional dose validation results of three groups plans in this study meet the clinical requirements ($\gamma \geq 90\%$). Although VMAT plan is more complex than IMRT plan and involves more parameters (collimator angle, multi-leaf grating, dose rate, gantry rotation speed) in the process of treatment implementation, the measurement results of VMAT plan are better than IMRT, which may be because Arccheck is cylindrical for the phantom, the subfield in VMAT is smaller, and the angle difference of probe dose response is smaller, which makes it more suitable for the measurement of VMAT plan [23–24].

In conclusion, under the condition that the prescription dose covered at least 95% of the PTV standard, whether using IMRT or VMAT technology in simultaneous integrated boost radiotherapy for prostate cancer can satisfy the needs of OAR and have a good dose verification pass rate. Compared with the IMRT plan, VMAT plan can reduce the treatment time significantly and improve the treatment effectively; 2ARC plan has similar target coverage; but the protection of bladder, rectum and small bowel is worse; the less the number of VMAT arcs, the worse the OAR protection, With the number of arcs increases the quality of plan improves, but at the same time, it the number of MUs and treatment time also increases. The results of this study show that for the complex target structure including prostate, seminal vesicle and pelvic lymph node drainage area, the use of IMRT technology can significantly improve the quality of planning, and can better protect the OAR, and is more suitable for the simultaneous integrated boost radiotherapy of prostate cancer pelvic radiation prevention. However, considering that the sample size used in this study is small the results need to be further verified by expanding the sample size.The plan designer needs to compare the advantages and disadvantages of VMAT and IMRT first with a larger sample size for cases with different target size or structure, weigh the gains and losses, and finally select a more appropriate treatment technology.

Conclusions

Compared with IMRT, VMAT noticeably improved delivery efficiency, with two arcs provided comparable tumor dosimetric coverage, performed worse in dose sparing for bladder, rectum and small bowel. IMRT plan was better than VMAT in prostate cancer radiotherapy using a simultaneous integrated boost.

Abbreviations

RT: Radiation therapy; ENI: Elective Nodal Irradiation; ADT: Androgen deprivation therapy; CT: Computed tomography; PTV: Planning target volume; CTV: Clinical target volume; GTV: Gross tumor volume; VMAT: Volumetric modulated arc therapy; Gy: Gray; IMRT: Intensity modulated radiotherapy; TPS: treatment planning system; HI: Homogeneity index; CI: conformability index; MU：monitor unit；OAR：Organs at risk

Declarations

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request

Authors’ contributions

SUN and WN analysed and interpreted the data, performed the statistical analysis and were major contributors in writing the manuscript. LY and CHEN helped with the statistical analysis and writing the manuscript. SUN, WN, LY, and CHEN helped drafting the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Figures

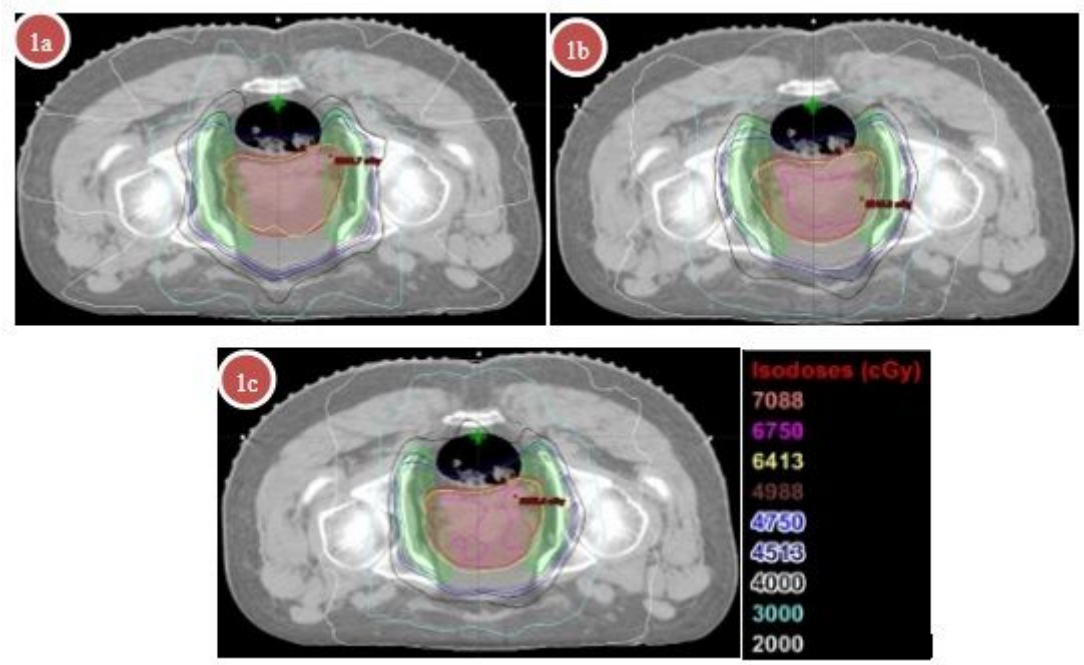

Figure 1

1a is plan 9F, 1b is plan 1ARC, and 1c is plan 2ARC.The red line is PTV1, the green line is PTV2, and the other color lines are isodose lines.