A Simple and Effective Method to Improve Pinnacle Auto-planning Based on Rectal Cancer

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Research

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Abstract

Background: Try to re-optimize the results of pinnacle Auto-planning (AP) and explore the feasibility of obtaining more dosiologically advantageous AP plans by reducing "experience-based optimization parameters".

Methods: 35 rectal cancer cases with preoperative radiotherapy were selected and all plans are designed retrospectively with Pinnacle9.1 AP. Firstly we take the doctor's clinical prescription as a universal optimization parameters, get the first reference group CP; secondly we set the results of manual plans (MP) which were already used for clinical treatments as the optimization parameters, replacing the physicist's initial experience, get the second reference group IE; at last we reduce the results of MP by 15% as the optimization parameters, get the control group T. By keeping the other optimization conditions unchanged, we designed AP plans for all three groups. Wilcoxon rank sum tests were performed for CP-T and IE-T based on the dosiological parameters of the planning target volume(PTV) and organs at risk(OARs).

Results: Dose distribution of all three groups was in a clinically acceptable range. The dose of OARs in T group was significantly lower than CP and IE,the differences were statistically significant.

Conclusion: Experience-based AP plan has a space for re-optimization, and appropriately reducing the results of MP as optimization parameters is a simple and feasible way.

Background

The development of automated planning aims to improve the efficiency of physicists and the quality of plans, so as to benefit patients ultimately. Pinnacle's AP is currently one of several mainstream automatic planning systems, which is an automatic planning system based on the Progressive Optimization Algorithm^[1-4]. Through the initial optimization parameters input by the user, it will simulate the thinking pattern of a senior physicist for the planned design, such as the delineation of the auxiliary organs and the use of different cost functions. The optimization results of Pinnacle AP are directly related to the settings of the optimization parameters, usually given by doctors and physicists, combined with clinical experience or with the help of some auxiliary tools such as PLAN IQ, etc^[5-8]. However, if the optimization parameters are not optimal, the output results of AP will also have a re-optimization space. Then the question is will there be a simple and viable way to re-optimize the results of the AP plan? In addition to the daily clinical work, we had tried to reduce the results of MP to a certain proportion (10% / 15% / 20%) as the initial optimization parameters to redesign the AP plans, and found that the results could improve to a certain extent. Based on pinnacle' AP, we designed this study to explore the feasibility of re-optimizing AP plans and sought to find a simple and effective way to re-optimize it^[9-11].

According to the latest global cancer burden report released by the Journal of the American Medical Association subsidiary JAMA Oncology, colorectal cancer has become the fourth highest incidence of

malignancy in the world, and the mortality rate is the second out of all tumors^[12]. Different from colon cancer, the location of the lymph drainage area of rectal cancer is relatively fixed, and the tumor bed location is within 15 cm from the anus, making the shape of PTV is roughly symmetrical. And the OARs around the PTV is handful, so it is very suitable for the rapid design of automatic planning to save planning time and benefit the majority of patients^[13].

Methods

Patient information

35 patients with rectal cancer treated in our institution in the past two years were randomly collected for a retrospective study, which has been approved by the ethics committee of our hospital, with the ethics number: B2020—357R. All patients had undergone 1 ~ 2 cycles of neoadjuvant chemotherapy before radiotherapy, and two more cycles after radiotherapy^[14–17]. Both PTV and OARs were delineated by clinicians according to RTOG criteria, GTV included the primary tumor sites and pelvic metastases, CTV included the whole pelvic lymphatic drainage area, and PGTV and PVCTV from GTV and CTV expanded 0.2 ~ 0.3cm^[18]. Normal tissue includes the small intestine, bladder, bilateral femoral head, and the skin. The PGTV dose was 50Gy/25fx, PCTV with a prescription dose of 45Gy/25fx. All cases were given uniformly prescribed and normal tissue limits by clinicians according to the NCCN guidelines and have been first designed for clinical treatment of MP by senior physicists^[19]

Planning and design

The usual practice of AP of pinnacle is to take the doctor's clinical prescription or the clinical experience of a senior physicist as optimization parameters. In this study, the doctor's Clinical Prescription was used as the universal optimization parameters, set the first reference group CP; we take the results of MP already used for clinical treatment as the optimization parameters, replacing the Initial Experience of the physicist, set the second reference group IE; we reduce the results of MP by 15% as the optimized parameter set control group (except the maximum dose limit of the small intestine was reduced by 100cGy) (see Table 1). By keeping the other optimization conditions unchanged, we designed AP plans for all three groups. After all these works, we have two implications here. If there is re-optimization space for the results of the IE, there will also be re-optimization space for plans using clinical experience as the optimization parameters. And from the dosiological perspective, if T group is finally superior to IE and CP, it shows that the universal AP plans has re-optimization space.

Except for the optimization parameters, the optimization conditions remained unchanged, where the optimization weights of the initial objective are given by physicians with more than 10 years of clinical experience in rectal cancer in the critical condition of OARs. All plans were designed using IMRT with 9 fields, with the Gantry angle starting at 180 ° and the remaining parameters are shown in Table 2. All results were rescaled to meet the prescription requirements of PGTV and PCTV and data statistics were performed by Dose Volume Histograms (DVH). For PGTV and PCTV, we assess Heterogeneity Index (HI),

Conformity Index (CI) and Gradient Index (GI), ($HI = D2\%/D98\%$, $CI = PTV^2/TV*PT$, $GI = v50/v100$). The closer HI and CI are to 1, the better, the smaller GI is, the better^[20–22]. For OARs, we assess the maximum dose, average dose and the volume irradiated by at least 30Gy of small intestine; volume and average dose of at least 30Gy; average dose and the volume irradiated by at least 40Gy of bladder; average dose of bilateral femoral bones.

Table 1
Settings for optimization goals

Structures	Functions	Optimization Goals (CP/IE/T)			Priority	Compromise
PGTV	5000cGy					
PCTV	4500cGy					
Bowel_small	Max Dose	5000Gy Δ	Outcomes	IE-100cGy	High	Yes
Bowel_small	Max DVH	V30 < 50%		85%Value	Low	Yes
Bowel_small	Mean Dose	/	MP	Of	Low	Yes
Bladder	Max DVH	V40 < 40%		IE	Medium	Yes
Bladder	Mean Dose	/			Low	Yes
Femur_L	Mean Dose	3000cGy			Medium	Yes
Femur_R	Mean Dose	3000cGy			Medium	Yes
Δ If PTV and small intestine overlap, it should be 5300cGy						

Table 2
Settings for other parameters

Type	value
Couch	0
Collimater	0
Dose Grid	0.2cm*0.2cm*0.2cm
Optimization Type	DMPO
Max Number of Segments	60
Engine Type	Biological
Max Iterations	60
Tuning Balance	11%
Dose Fall-Off margin	2.6
Hot-Spot Maximum Goal	107%
Use Cold-SSpot ROIS	Yes

Data analysis

Normality test was executed for the optimization results with SPSS 22.0 and found that 6 sets of data did not conform to the normal distribution. We performed Wilcoxon rank sum tests for the optimization results of CP-T and IE-T, and the results are expressed as median, $P < 0.05$ represents statistically significant differences.

Results

The results of the CP-T group are shown in Table 3 and IE-T are shown in Table 4.

The coverage of PTV in all three groups met the clinical requirements, bringing at least 95% volume of the PTV to the prescribed dose. For CP-T : HI and CI of PGTV ,HI of PCTV in T group were worse than that in CP, the difference was statistically significant ($P < 0.05$); the CI of PCTV in T group was also worse than that in CP, but the difference was not statistically significant ($P > 0.05$). For IE-T : HI of PGTV and PCTV in T group were worse than that in CP, the difference was statistically significant ($P < 0.05$); the CI of PGTV and PCTV in T group was worse than that in CP, and the difference was not statistically significant ($P > 0.05$). There was no statistically significant significance for differences in GI between T and reference groups ($P > 0.05$). In terms of fitness and uniformity of the target region, the difference between the T and reference groups was essentially within 1%.

For OARS, the T group outperformed the two reference groups, including the maximum dose, V30 and average dose of the small intestine, V40 and average dose of the bladder, average dose of bilateral femoral head, the difference was statistically significant ($P < 0.05$).

Table 3
Results of statistical tests for CP-T

Goals	CP	T	Z	p
PGTV,V50,%*	96.01	96.31	-0.88	0.38
PCTV,V45,%*	96.36	95.93	3.17	0.02
PGTV,HI *	1.04	1.04	-3.85	< 0.01
PGTV,CI	0.82	0.81	3.96	< 0.01
PCTV,HI	1.15	1.15	-4.77	< 0.01
PCTV,CI *	0.86	0.86	-1.57	0.12
GI	3.55	3.53	1.67	0.10
Bowel_small,Dmax,cGy *	4831.4	4803.6	2.34	0.02
Bowel_small,V30,cGy *	25.1	19.98	5.14	< 0.01
Bowel_small,Dmean,cGy	2330.4	2283.7	4.46	< 0.01
Bladder,V40,%	30.85	21.52	5.06	< 0.01
Bladder,Dmean,cGy	3264.3	3076.1	4.95	< 0.01
Femur_L,Dmean,cGy	1589.3	1372.7	3.49	< 0.01
Femur_R,Dmean,cGy	1440.1	1357.5	3.37	< 0.01
The bands * in Goals are data that did not fit the normal distribution.				

Discussion

In this study, we set the clinical prescription of clinicians and initial experience of physicists as optimization parameters to get group CP and IE respectively base on preoperative rectal cancer, exploring the feasibility of re-optimizing automatic plans in pinnacle9.1 AP.

Table 3 Table 4 shows that the fitness and uniformity of the T group decreased compared to the CP and IE groups. This difference was more obvious between the CP and T groups, mainly due to the loose conditions and OARs were not fully optimized, so the CP group had better homogeneity and moderation. While the initial conditions of the IE group were generated by the MP program and had undergone a round of manual optimization by physicists, so the dosiological difference in the target regions between them was not distinct. For overall quantification, the difference in HI,CI,GI in both the T and reference groups

was within 1%. Figure 1 shows the comparison of the different dose distributions obtained by a patient with the three groups, which shows slight difference in fitness and uniformity among them. After the doctor's evaluation, it was considered difficult to distinguish the difference clinically, and the dose distribution of all the three groups was within a clinically acceptable range.

Table 4
Results of statistical tests for IE-T

Goals	IE	T	z	p
PGTV,V50,%*	96.12	96.31	-1	0.32
PCTV,V45,%*	96.07	95.93	2.6	0.01
PGTV,HI *	1.04	1.04	-2.67	0.01
PGTV,CI	0.80	0.81	1.02	0.31
PCTV,HI	1.15	1.15	-3.42	< 0.01
PCTV,CI *	0.86	0.86	-0.84	0.40
GI	3.56	3.53	1.67	0.10
Bowel_small,Dmax,cGy *	4802.5	4803.6	2	< 0.05
Bowel_small,V30,cGy *	20.73	19.98	4.57	< 0.01
Bowel_small,Dmean,cGy	2275.5	2283.7	2.34	0.02
Bladder,V40,%	24.08	21.52	5.11	< 0.01
Bladder,Dmean,cGy	3071.7	3076.1	3.06	< 0.01
Femur_L,Dmean,cGy	1516.3	1372.7	5.11	< 0.01
Femur_R,Dmean,cGy	1477.4	1357.5	4.18	< 0.01
The bands * in Goals are data that did not fit the normal distribution.				

Figure 2 shows the dosiological differences in OARs between the three groups in a boxtype manner. Compared to the reference groups, T group better protected the normal tissues in the pelvic region, including the bladder, small intestine, and bilateral femoral bones. Such an advantage is more obvious between the CP group, and the reason remains that the conditions of the CP group are based on clinical needs and have more space for further optimization. But even against the IE group based on the clinical experience of physicists, the T group in normal tissues protection was also evident, with the average dose of the femoral head even reduced by 10%. Considering that neoadjuvant chemotherapy is patients before and after radiotherapy, reducing the dose of OARs is important to reduce the occurrence of side reactions and improve long-term quality of survival^[23–26]. Moreover, although this study is taking rectal cancer as

an example, considering that targeted therapy or immunotherapy combined with radiotherapy will take the mainstream in future treatment of different tumors, how to reduce the side effect of OARs is always the goal of clinical adherence on the basis of rapid planning.

Overall, the T group ensures the coverage, fitness and uniformity of PGTV and PCTV, which effectively reduces the dose of OARs and has more dosiological advantages, indicating that there is a re-optimization space for the experience-based AP plans.

The disadvantage is that if we try to improve the quality of AP plans through the method of this study, the MP plan must be firstly designed so as to set the reduced results as optimization parameters. So is there a simpler and more feasible way? The answer is sure, and both pinnacle's PLAN IQ and Varian's Rapid Plan(RP) can perform first-step machine learning based on the MP before predicting the results based on new patients. By using these tools, we obtained a simple and feasible way to reoptimize the preoperative rectal cancer AP program.

Despite the advantages of the AP plans, we found deviation values for OARs in this study (see bladder deviation in Fig. 2), so clinicians and physicists should strictly examine their results. In addition, only 35 patients were enrolled in this study, and some of the optimization results did not meet the normal distribution, resulting in the final adoption of the Wilcoxon rank sum tests, and the statistical conclusions were slightly less convincing. We believe that it is necessary to pre-screening patients before designing AP plans, and we will continue this study in later clinical works, increasing the number of cases while improving the methods.

Conclusion

Through the comparison of control group and reference groups, we verified that experience-based AP plans had re-optimization space. By reducing the results of the MP plan as the initial optimization parameters, the experience-based AP plan can be effectively re-optimized, reducing the dose of OARs while ensuring the coverage, fitness and uniformity of PTV. We also propose a simple and effective way to re-optimize AP plans, namely to get the predicted plan results using PLAN IQ,RP and then set them as optimization parameters.

Declarations

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Authors' contributions

Lei Hua and Gang Chen contributed equally to this work

LH, GC and JYZ designed the entire study. LH designed the plans, collected data and wrote the manuscript. GC collected patient information and delineated PTV and OARs. HX applied for ethics. XOP delineated PTV and OARs. JYZ revised the manuscript critically and substantially. All authors read and approved the final manuscript.

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Availability of data and materials

The materials used and data sets analysed in the current study are available from the corresponding author on reasonable request

Ethics approval and consent to participate

This research has been approved by the ethics committee of our hospital, with the ethics number: B2020–357R

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

Comparison of different dose distributions among the three groups.

Figure 2

Statistical difference of OARs in dosimetry among the three groups.