EP-1552: Robust optimization for IMPT of pencil-beam scanning proton therapy for prostate cancer

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significance was not reached.

Table1 . Comparison between IRIS and MLC over 21 Liver SBRT plans

	IRIS	MLC	p
PTV coverage %	97.4 (1.44)	97.7 (1.4)	0.7
PTV gEUD Gy	40.3 (6.5)	40.1 (6.9)	0.9
Prescription isodose %	70.5 % (3.4)	73.2% (3.6)	**0.03**
nCI	1.15 (0.04)	1.16 (0.05)	0.42
HI	1.42 (0.06)	1.37 (0.07)	**0.02**
GI	3.13 (0.36)	2.65 (0.21)	**< 0.001**
Liver Dmean Gy	8.8 (4.0)	7.9 (3.4)	0.46
Liver $V_{15Gy(21Gy)}$ cm^3	160.0 (111.3)	138.6 (95.6)	0.53
Duodenum Dmean Gy	2.9 (2.8)	2.4 (2.4)	0.6
Stomach Dmean Gy	3.5 (1.4)	2.7 (1.5)	0.11
Bowel Dmean Gy	1.1 (0.8)	0.4 (0.4)	**0.003**
Treatment time (min)	34.7 (6.1)	29.2 (6.7)	**0.01**
MU	27561 (6660)	24044 (6650)	**0.11**

Conclusion

MLC plans offer equivalent coverage and OAR dose sparing when compared to IRIS plans for Liver SBRT. An improvement in dose gradient was observed for MLC plans.MLC provided more efficient delivery with a significant reduction in treatment time. The need to prescribe to higher isodose levels when using MLC, requires, however, further investigation.

EP-1551 Radiobiological optimization and plan evaluation in IMRT planning of prostate cancer

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Purpose or Objective

The aim of this study is to compare treatment plans optimized by dose volume objectives (DVO) to plans optimized with radiobiological objectives (RBO) or optimized by combining both DVO and RBO (Mixed)

Material and Methods

14 patients with prostate cancer previously treated with IMRT plans (Treatment Planning System: Pinnacle[3]) optimized by Dose Volume Objectives (DVO), were re-planned by radiobiological optimization of gEUD objective functions (RBO) and using combined DVO and RBO, (Mixed Objectives). The prescribed dose to the target of patients varies between 70-78 Gy, delivered in 2 Gy/fraction. The plans were evaluated by dose volume indices (Conformity Index, CI, for PTV and D1%, D15%, D25% and D40% for both rectum and bladder, where Dx is the Dose received by x% of the volume of the OAR) and by radiobiological indices (TCP, NTCP and complication free control probability P+). The Poisson\LQ model and Kallman s-model were used in calculation of TCP and NTCP, respectively.

Results

The mean and standard deviation (SD) values of TCP for DVO, RBO and Mixed objectives plans were 0.914±0.05, 0.895±0.07 and 0.912±0.06 respectively. Mean and SD values for NTCP were 0.0413±0.03, 0.0387±0.02 and 0.0365±0.03 for DVO, RBO and Mixed respectively, while P+ mean and SD values for the three objective techniques were 0.872±0.06, 0.8557±0.07 and 0.874±0.05, respectively. The mean value of CI of PTV and D40% for rectum and bladder were 0.805±0.08, 34±0.18Gy, 28±0.6 Gy for DVO, 0.739±0.11, 21.4±0.27 Gy, 21.7±0.72 Gy for RBO and 0.853±0.045, 25.9±0.22 Gy, 22.6±0.72 Gy for mixed objectives.

Conclusion

For OAR mean dose values we found that RBO gives the lowest doses compared to both DVO and mixed plans, while TCP values in DVO and Mixed plans were better than RBO. DVO and Mixed plans provide comparable TCP values while RBO gives the lowest TCP values. As to CI, Mixed plans win over both DVO and RBO. In conclusion, by using mixed radiobiological and dose-volume objectives it improves the conformity to the target and also NTCP of the plan, giving at the same time a comparable TCP as DVO plans.

EP-1552 Robust optimization for IMPT of pencil-beam scanning proton therapy for prostate cancer

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Purpose or Objective

Proton therapy for prostate cancer has the potential of delivering high dose to the tumor whilst sparing normal tissue to minimize GI/GU toxicity. In the traditional PTV-based multifield optimized intensity modulated proton therapy (MFO-IMPT) approach to treatment planning for prostate cancer, the PTV is commonly defined through expansion of the CTV to account for setup and range uncertainties. In contrast to this method, the robust optimization approach to IMPT planning does not require the intermediate and somewhat arbitrary step of defining the PTV. Instead, the optimizer is tasked with finding a treatment plan which best meets the clinical objectives under the setup and beam range uncertainties which are explicitly expressed as the input parameters to the treatment planning process. The goal of this study was to apply the robust optimization method for IMPT treatment planning for prostate cancer and evaluate the results against the traditional PTV-based IMPT treatment planning strategy.

Material and Methods

For five $T_{1-3}N_0M_0$ prostate cancer patients two types of MFO-IMPT treatment plans were created in Raystation 4.99 (RaySearch Laboratories AB, Sweden) treatment planning system: a PTV-based plan and a robustly optimized CTV-based plan. The PTV margin for CTV_{70} was defined as 5 mm in all directions. The robustness parameters for the robust optimization were set to 5 mm and 3% for setup translational uncertainty and range uncertainty, respectively, and the optimization was performed using the 'minimax' method implemented in Raystation. Treatment plans were normalized to $D_{98\%}$ of the CTV_{77}. The plans were evaluated for robustness by simulating translational and rotational setup errors of the planning CT by ±5 mm and ±2º (yaw and roll), respectively. In addition, the range uncertainty was simulated by scaling the HU of the planning CT by ±3%. By combining the above robustness evaluation modes a total of 260 dose scenarios per plan was obtained. The target coverage robustness was assessed by comparing the voxelwise-minimum (a metric constructed by finding a minimum value of dose in each voxel independently for all the dose scenarios) and average $V_{95\%}$ of the CTV_{70}. To compare dose to the rectum, the entire DVH of the rectum was evaluated for the nominal dose as well as the voxelwise-maximum dose.

Results

The $V_{95\%}$ of the CTV_{70} calculated from the voxelwise-minimum DVHs were consistent (>99%). Also, the average $V_{95\%}$ over all dose scenarios of the CTV_{70} were comparable (>99%). The benefit of the robust treatment planning approach was apparent for the rectum dose where the dose is lower for the robustly optimized plan in both the nominal as well as in the perturbed dose scenarios (nominal and voxelwise-maximum dose presented in Figure 1). Only for doses >70 Gy, the CTV-based plans resulted in a slightly higher irradiated rectum volume than the PTV-based plans.

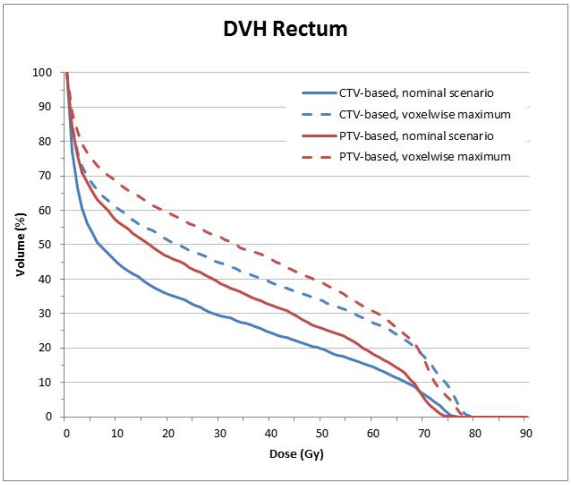

Figure 1. DVH of the rectum for the CTV-based as well as the PTV-based IMPT treatment plan

Conclusion

The CTV-based robustly optimized treatment plans maintain target coverage, while providing a lower dose to the rectum.

EP-1553 Dose reduction of femoral heads using volumetric-modulated Dynamic WaveArc for prostate cancer

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Purpose or Objective

Although hip fracture is a rare complication in radiation therapy for prostate cancer (PCa), it is a major cause of morbidity and mortality in elderly patients. Therefore, the femoral heads are the major organs at risk (OARs) in treatment planning of PCa and reduction of doses to the femoral heads could be important. A new irradiation technique, termed volumetric-modulated Dynamic WaveArc (DWA), has been developed. Figure 1 shows the trajectory of DWA beam. An X-ray head with multileaf collimators mounted on an O-ring gantry allows combining simultaneous rotation of the gantry and O-ring, resulting in sequential noncoplanar intensity-modulated beam delivery in a short treatment time, without a couch rotation. Since the bilateral femoral heads were located on the same level as the planning target volume (PTV) in PCa patients, DWA would reduce the doses to the bilateral femoral heads. We performed a planning study using coplanar volumetric-modulated arc therapy (coVMAT) and DWA to compare the dose distribution of PTV and OARs, beam-on time, and monitor units (MU).

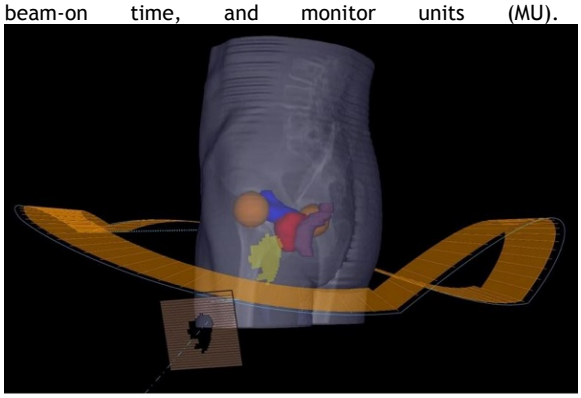

Figure 1 Trajectory of DWA beam.
Red: PTV, Orange: Bilateral femoral heads, Brown: Rectum, Blue: Bladder

Material and Methods

The coVMAT and DWA plans were created for 20 patients with PCa respectively using RayStation version 4.7 and Vero4DRT. All plans were created using one full arc and the prescribed dose was 76 Gy in 38 fractions as a mean dose to PTV. We compared the dose distributions of OARs (bilateral femoral heads, rectal wall, and bladder wall) and PTV, beam-on time, and MU using a paired t test, and a significance level of less than 5% ($p < 0.05$) was considered statistically significant.

Results

Table 1 shows the plan comparison between coVMAT and DWA. The mean doses and D1cc of the bilateral femoral heads in coVMAT/DWA plans were 11.8/9.1 Gy ($p < 0.001$) and 21.8/18.5 Gy ($p < 0.001$), respectively. Although the mean volume of bladder wall irradiated greater than 10, 20, 30 and 40 Gy (V10-40) were significantly larger in DWA plans compared with coVMAT, the mean volume of rectal wall irradiated greater than 10, 20, and 70 Gy (V10, V20, and V70) were significantly smaller in DWA plans. The conformity index and homogeneity index were similar in both plans. The mean beam-on time and MU in coVMAT/DWA plans were 70.6/73.5 seconds ($p = 0.045$) and 427/454 MU ($p = 0.041$), respectively.

Table 1 Plan comparison between coVMAT and DWA

	coVMAT	DWA	p-value
Femoral Heads			
Mean Dose [Gy]	11.8	9.11	< 0.001*
D1cc [Gy]	21.8	18.5	< 0.001*
Rectal Wall			
V10 [%]	95.4	91.4	< 0.001*
V20 [%]	86.9	83.4	< 0.001*
V30 [%]	64.6	65.4	0.64
V40 [%]	35.3	35.4	0.82
V50 [%]	25.5	25.7	0.35
V60 [%]	18.7	18.6	0.35
V70 [%]	9.22	8.04	< 0.001*
Bladder Wall			
V10 [%]	52.2	60.1	< 0.001*
V20 [%]	43.2	45.8	0.001*
V30 [%]	33.4	35.2	0.006*
V40 [%]	26.2	26.7	0.03*
V50 [%]	20.9	21.2	0.08
V60 [%]	17.0	17.1	0.80
V70 [%]	13.3	13.2	0.06
Conformity index	89.51	89.48	0.63
Homogeneity index	11.03	11.48	0.42
Beam-on time [sec]	70.6	73.5	0.045*
Monitor unit [MU]	427	454	0.041*

* Asterisks (*) indicate the statistical significance of the factors.