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Automated iterative plan optimisation widens therapeutic window for prostate cancer arc therapy

E.J.L. Brunenberg[1], J.M.A.M. Kusters[1], P.G.M. Van Kollenburg[1], C.M. Verhagen[1], P.M.W. Van Herpen[1], M. Wendling[1], R.J. Smeenk[1], P.M. Poortmans[1]
[1]*Radboud UMC, Radiation Oncology, Nijmegen, The Netherlands*

Purpose or Objective: Treatment planning for volumetric modulated arc therapy (VMAT) is complex, as the result is highly dependent on the selected optimization objectives. The Auto-Planning module in Pinnacle³ 9.10 (Philips Healthcare, Fitchburg, WI, USA) aims at offering efficient automated planning that directly uses clinical goals for iterative optimization, pushes beyond these goals if possible, and delivers consistent plan quality. In this study, we compared the performance of two Auto-Planning techniques with our original clinical approach of manually optimized prostate cancer VMAT plans.

Material and Methods: Techniques were evaluated for 23 prostate cancer patients (all treated using a rectal balloon), 18 of which underwent primary irradiation with a prescription dose (PD) of 70 Gy in 28 fractions. PTV (planning target volume) for these cases ranged from prostate only to prostate plus entire seminal vesicles. Five patients received salvage treatment with 65 Gy in 26 fractions.
Two Auto-Planning techniques (AP1, AP2) were compared with the manually optimized clinical plan (MP) to evaluate plan quality, focusing on PTV coverage and OAR (organ at risk) sparing. AP1 contained clinical goals for rectal wall, anal wall, bladder and femoral heads (dose-volume relationship and mean dose goals). AP2 used the same technique, excluding the femoral heads, in order to focus on bladder, rectal and anal wall (which are more prone to toxicity), and including a goal to minimize dose on tissue outside PTV and OARs.
Monitor units (MUs) for all plans were scaled to achieve a V95% ≥ 99% for the PTV. One 10 MV VMAT arc (95 to 265° counterclockwise) and two portal imaging beams (for online position verification, 5 MU each) were used.

Results: Table 1 presents the results of the comparison. Both AP techniques show a significant increase in PTV mean dose and number of MU when compared to MP, while PTV max dose is not significantly different. With respect to OARs, Auto-Planning significantly spares all considered structures. AP2 indeed sacrifices sparing of femoral heads for more sparing of bladder, rectal and anal wall. See Figure 1 for an example of dose distributions and DVHs (dose volume histograms).
We selected AP2 as our Auto-Planning technique for clinical use. For 10 subsequently treated patients, AP2 resulted in an approved plan on the first Auto-Planning run for all 8 patients undergoing primary irradiation. The 2 salvage patients needed extra goals for the femoral heads.
Delta-4 measurements for 20 patients treated with AP2 showed a mean gamma pass rate of 98.4 ± 1.4 %, while EBT3 film QA on a subset of 10 patients resulted in a mean gamma pass rate of 97.4 ± 1.2 % (evaluated for 3%/3mm).

Conclusion: Besides its efficiency and consistency, Auto-Planning offers similar PTV coverage as the original clinical plans, combined with better sparing of bladder, rectal and anal wall. Thus, the module widens the therapeutic window and is now used as our clinical standard for prostate cancer VMAT planning.

Structure	Criterion	MP	AP1	AP2
PTV	mean dose (% of PD)	100.1 ± 1.2	101.1 ± 0.5*	101.2 ± 0.8*
	max dose (% of PD)	103.8 ± 1.7	104.2 ± 0.9	104.3 ± 1.2
bladder	V60Gy (%)	19.9 ± 10.7	16.8 ± 10.1*	16.5 ± 10.0*
	mean dose (Gy)	29.9 ± 10.6	**27.7 ± 11.0*°**	**26.4 ± 10.4*°**
rectal wall	V60Gy (%)	22.2 ± 6.7	20.3 ± 6.5*	20.3 ± 6.5*
	V30Gy (%)	37.4 ± 10.5	**34.7 ± 11.6*°**	**33.8 ± 10.8*°**
	mean dose (Gy)	29.8 ± 5.4	**28.0 ± 6.5*°**	**27.2 ± 6.5*°**
anal wall	mean dose (Gy)	21.0 ± 8.4	16.7 ± 8.4*	16.7 ± 8.5*
rectal + anal wall	V60Gy (%)	18.8 ± 6.0	16.7 ± 5.5*	16.7 ± 5.5*
	V30Gy (%)	34.4 ± 9.4	**30.6 ± 9.7*°**	**29.9 ± 9.2*°**
	mean dose (Gy)	27.5 ± 4.9	**25.0 ± 5.4*°**	**24.4 ± 5.5*°**
femoral head (left)	max dose (Gy)	47.2 ± 7.2	**40.1 ± 8.6*°**	**46.1 ± 7.8°**
	mean dose (Gy)	33.1 ± 6.2	**24.4 ± 6.4*°**	**30.6 ± 6.1*°**
femoral head (right)	max dose (Gy)	46.7 ± 6.4	**39.5 ± 8.1*°**	**48.0 ± 7.4°**
	mean dose (Gy)	32.8 ± 5.2	**23.4 ± 4.9*°**	**32.1 ± 5.7*°**
-	# MU VMAT arc	475 ± 74	560 ± 58*	546 ± 58*

Table 1: Comparison of manually optimized (MP) and Auto-Planning (AP) techniques: mean values and standard deviations for 23 patients. */gray: AP significantly different from MP; °/bold: significant difference between AP1 and AP2 (two-sided paired t-test used, p<0.05).

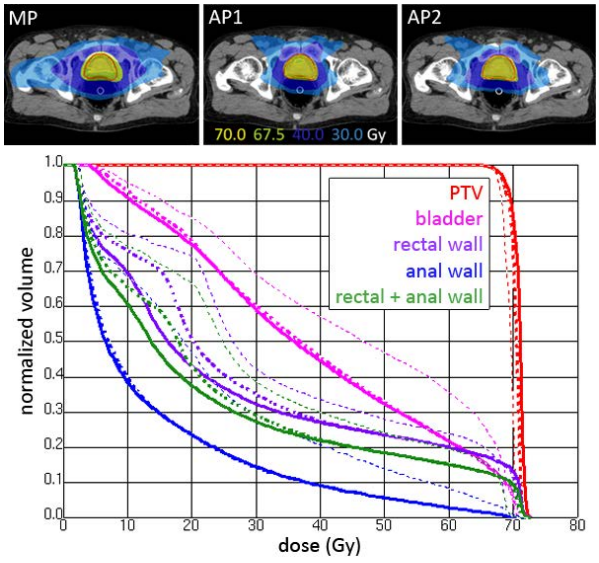

Figure 1: Example of dose distributions and DVHs belonging to MP, AP1 and AP2 for a 70-Gy plan. DVHs show MP as thin dashed; AP1 as thick dashed; AP2 as thick solid.

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mARC treatment planning in non-dedicated systems: two conversion approaches using IMRT and SmartArc

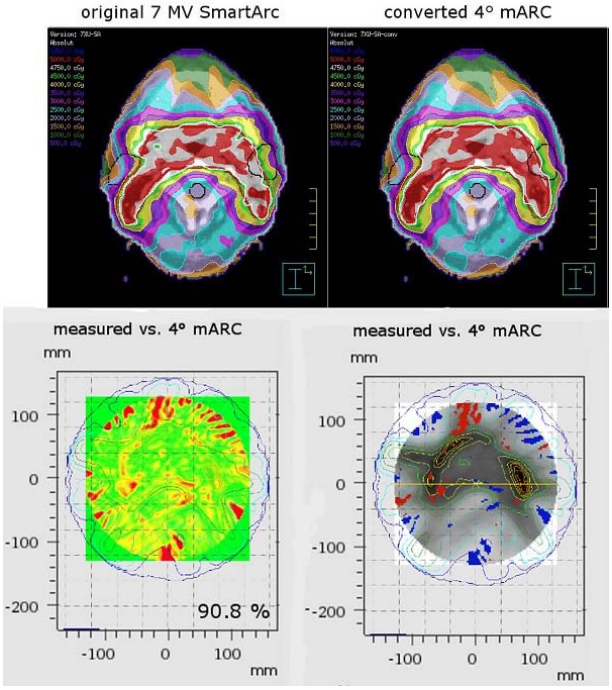
Y. Dzierma[1], N. Licht[1], I. Norton[2], F. Nuesken[1], C. Rübe[1]
[1]*Universitätsklinikum des Saarlandes, Department of Radiation Oncology, Homburg/Saar, Germany*
[2]*Philips Healthcare, Philips Radiation Oncology Systems, Zürich, Switzerland*

Purpose or Objective: The modulated arc (mARC) technique is Siemens analogue to volumetric modulated arc therapy (VMAT), with a different underlying principle and technical implementation. While this presents the only available rotational technique for existing Siemens users, only few treatment planning systems (TPS) are capable of mARC planning. In particular, the widespread Philips Pinnacle TPS does not support mARC. The purpose of this work is to present two solutions for mARC plan creation starting from either IMRT or SmartArc plans.

Material and Methods: In the first approach, the user creates a step-and-shoot IMRT plan with any number of beams ordered either clockwise or counter-clockwise, and one segment per beam. If desired, a few beams with more than one segment can be included. This plan is then exported as RT-Dose and an in-house software is used to modify the file in such a way that it is interpreted by the linac as an mARC plan. For this aim, each single-segment beam is converted into an arclet of a user-specified length (usually 4°). The calculated dose distribution of the IMRT plan corresponds to the mARC treatment, because mARC dose is usually

calculated under the assumption of stationary arclet delivery.
The second method is a dedicated solution for mARC planning in Philips Pinnacle (V9.2 or higher) without the detour of an external software. In this approach, a SmartArc (VMAT) plan is created in the TPS with 8° final spacing of optimization points. Then a Pinnacle script is applied which duplicates and shifts the optimization points in such a way to separate phases of beam on and of MLC movement. This resulting plan is still treated like a SmartArc plan in the TPS, but irradiated as mARC at the linac.
We present the proof-of-principle and dosimetric verification using the PTW Octavius rotation unit with 2D-array.

Results: A number of plans were created for prostate and head-and-neck cancer. All converted plans could be irradiated without problems. 3D dose distributions agree with the calculated dose distributions (mARC and approximated stationary field plan) within the gamma criteria for IMRT verification (over 90 % of the points passing the criteria of 3 % deviation in local dose, 3 mm distance to agreement, for all dose values above 10 % of the maximum, example in Figure).



	1st approach: IMRT to mARC	2nd approach: SmartArc to mARC
Starting plan:	**IMRT plan**	**SmartArc plan**
Specifications:	• Beams ordered (either clockwise or counter-clockwise) • Number of segments ≈ number of beams • Collimator angle constant • Same beam energy	• Final spacing of optimization points = 8° (set by script) • Only works in Philips Pinnacle with SmartArc
Workflow:	• Export plan as RTPlan • Run conversion script (linux-based) • correct cross-sum check • import in Mosaiq and send to machine for treatment	• run script in Philips Pinnacle • re-calculate dose distribution • export plan for treatment
User choices:	• if #segments = #beams, this will become an mARC plan • if a beam holds more than 1 segment, this will become a hybrid field • any number of beams with any spacing • any arclet length	• any number of rotations
Limitations:	• generally just one rotation, more rotations require manual separation of beams into several plans	• always creates arclets of 4° length spaced 8° apart
Dosimetric accuracy:	**As good as for a dedicated mARC planning system**	
Treatment stability:	**As good as for a dedicated mARC planning system**	

Conclusion: Both solutions offer the possibility of mARC planning inside a non-dedicated TPS. If Philips Pinnacle with SmartArc is available, plan creation is straightforward and can be performed inside the TPS. Otherwise, a special format of IMRT plan is required, which is externally modified before treatment. In both cases, good dosimetric accuracy is achieved, making this a viable solution for the creation of mARC treatment plans inside any treatment planning system.

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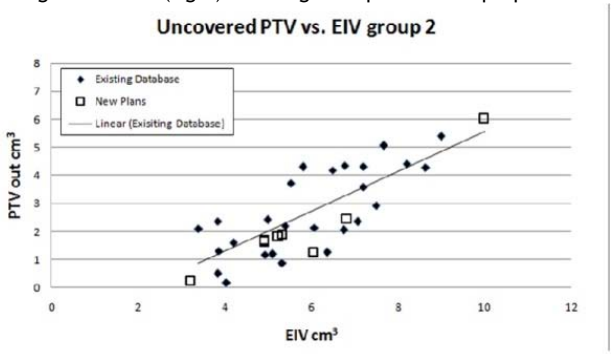
Spinal SBRT: improving plan quality using an existing database and a geometric parameter

L. Masi[1], R. Doro[1], I. Bonucci[2], S. Cipressi[2], V. Di Cataldo[2], I. Peruzzi[1], L. Livi[3]
[1]*IFCA, Medical Physics, Firenze, Italy*
[2]*IFCA, Radiation Therapy, Firenze, Italy*
[3]*Azienda Ospedaliera Universitaria Careggi, Radiation Therapy, Firenze, Italy*

Purpose or Objective: The achievable PTV coverage of spinal SBRT treatment plans depends on the spatial relationship between cord and target. PTV coverage is often sacrificed to fulfill the cord constraints and there are no objective criteria to determine whether an optimal coverage has been achieved. This may lead to suboptimal plan quality and to dependence on the planner's experience. A method to predict the achievable PTV coverage is proposed, which is based on an existing database and on a geometric parameter related to the cord-target 3D distance.

Material and Methods: A clinical database of 70 spine SBRT plans, 41 first treatment and 29 retreatment cases, delivered by the Cyberknife either in 3 fractions or in one fraction is used. TG101 cord constraints or stricter limits for reirradiation were applied. The 3D distance of cord to target was quantified by the expansion-intersection volume (EIV) [M.Descovich (2013)] adapted to spine and calculated as the intersection of the CTV and the cord, both expanded by 5 mm. Plans were classified into 3 groups according to the ratio of the prescribed dose to the cord maximum dose (PD/cordDmax): 1) 1.1-1.65; 2) 1.66-1.9; 3) 1.91-2.9. For each group the correlation between EIV and the PTV coverage was studied, analyzing the linear regression between EIV and the uncovered target volume (PTVout). As validation EIV was calculated for 20 new cases, the expected PTVout value computed by the regression equation and the plans optimized aiming to obtain the predicted coverage respecting the OAR constraints.

Results: EIV values ranged from 0.3 to 18 cc indicating a representative sample of the possible anatomical configurations. Average PTV coverage was 91.2% (range 81.5-98.6%). A significant ($p < 0.01$) positive correlation (Pearson's $r > 0.67$) was observed between EIV and the uncovered PTV (PTVout) over the 3 groups, confirming that for larger EIV, lower coverages are expected. The slope of the 3 respective regression lines increased from 0.67 to 0. 8 for increasing PD/cordDmax. For 16 out of the 20 new plans PTV coverage was higher than the predicted value, i.e PTVout was below the regression line (fig.1) fulfilling the optimization purpose.



Conclusion: This study confirms that EIV is a good parameter to represent the cord-target 3D distance in spinal SBRT. The analysis accounted for the interplay between anatomical characteristics and required dose gradient. The results