

Volumetric modulated arc therapy using multi-criteria dose plan optimization for anal cancer – feasibility of selective sparing of organs at risk

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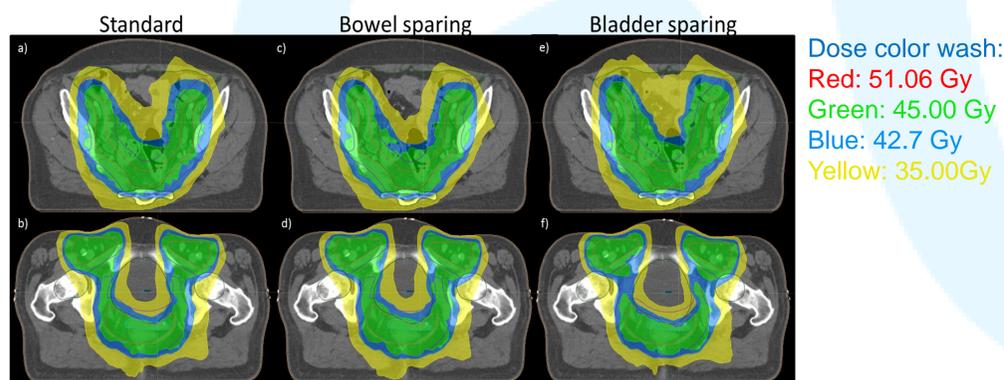
Background/Purpose

A traditional approach for inverse dose planning does not guarantee a Pareto-optimal dose distribution. Optimality is necessary to justify trade-offs between different organs at risk (OAR). Individual customization of dose plans with respect to differential sparing of OARs can be feasibly implemented as plan selection from a family of optimal plans. This has been shown for anal cancer intensity-modulated radiotherapy (IMRT) using multi-criteria dose plan optimization (MCO) (Rønde et al, Acta Oncologica 2017 56(10), 1277). We now present results for the trade-off options available using volumetric modulated arc therapy (VMAT) MCO-based plan selection.

Methods and Materials

- Retrospective dose plans for **10 representative anal cancer patients** (5 men and 5 women). Tumor stages T1, T2 and T4 – all M0.
- VMAT** with simultaneous-integrated tumour boost (53.75 Gy/45 Gy in 25 fractions).
- Four dual-arc VMAT treatment plans generated for each patient:**
 - One non-MCO VMAT plan** optimized with physician-defined organ-sparing priorities
 - Three VMAT-MCO dose distributions**, representing a span of clinically relevant objectives. All generated using **multi-criteria optimization (MCO)**:
 - Minimum acceptable target coverage with physician-defined organ-sparing priorities
 - Maximum bowel sparing without losing target coverage (if needed at the expense of the bladder)
 - Maximum bladder sparing without losing target coverage (if needed at the expense of the bowel)
- Software: **RayStation®** (v5.99.0.16 research build)

The quality of the VMAT-MCO plans was compared to the quality of the non-MCO VMAT plans, and the ability of the MCO module to selectively spare OARs (bladder or bowel) with VMAT-MCO was compared to the previously published results for IMRT-MCO (Rønde et al, Acta 2017).



Dose distribution for a female patient in transversal view. Standard (1) at the plane of the bowel a) and the bladder b). Bowel sparing (2) at the plane of the bowel c) and the bladder d). Bladder sparing (3) at the plane of the bowel e) and the bladder f). Shown are the Clinical Target Volume (CTV-N), Planning Target Volume (PTV-N), vagina, femoral heads, bowel and bladder.

Conclusion and perspectives/outlook

This study demonstrates that preference-informed dose planning with VMAT-MCO is indeed feasible. Selective sparing of OARs in VMAT-MCO facilitates the same trade-offs as IMRT-MCO, but with significantly reduced options for dose redistribution. The available space for dose re-distribution is strongly variable from patient to patient as was the case for IMRT-MCO, hence it is necessary to examine the plan dose trade-offs on an individual patient basis.

We found the calculation time for VMAT-MCO considerable longer compared to IMRT-MCO, although this may relate to the specific version of the research build employed.

RaySearch are continuously working on improving the MCO module and we plan to test a new research version later this year which should have taken some of the mentioned issues into consideration.

Acknowledgement

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Results

All 40 plans satisfies constraints for target coverage (CTV: V95%=100% and PTV: V98%≥95%).

Non-MCO VMAT vs. VMAT-MCO:

Non-MCO plans had higher Conformity Index (CI) compared to VMAT-MCO. VMAT-MCO plans had smaller hotspots in elective volumes, but higher dose volumes to bowel.

VMAT-MCO vs. IMRT-MCO:

Compared to IMRT-MCO, VMAT-MCO demonstrated smaller hotspot and lower CI.

VMAT-MCO allowed for redistribution of dose between bladder and bowel, but the optimization space was smaller than for IMRT-MCO and for VMAT-MCO plans the dose to bowel and bladder where higher than for IMRT-MCO. Time spent on optimization was longer for VMAT-MCO due to considerable increase in the calculation and conversion time compared to IMRT-MCO.

Conformity Index (CI)

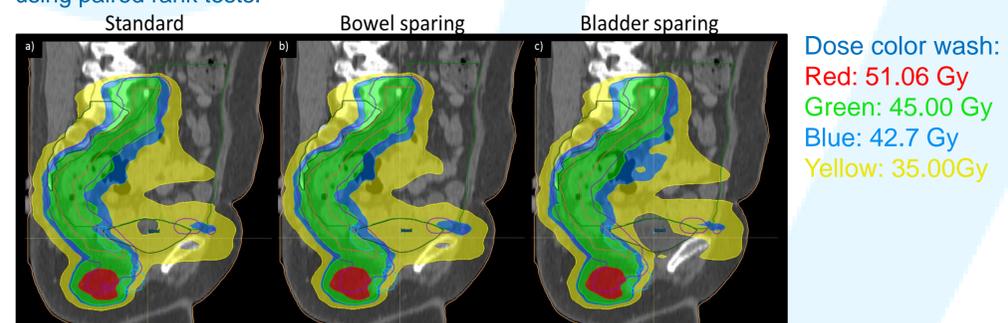
Priority	Standard	Standard	Standard	Bowel	Bowel	Bladder	Bladder
	non-MCO	MCO		MCO		MCO	
Modality	VMAT	IMRT	VMAT	IMRT	VMAT	IMRT	VMAT
CI	0.72 (0.69-0.76)	0.72 (0.70-0.73)	0.69 (0.67-0.70)	0.72 (0.69-0.70)	0.69 (0.68-0.70)	0.69 (0.66-0.70)	0.68 (0.67-0.68)

Plan Conformity Index (CI) defined as $CI = (V95\% PTV)/(V95\% Body)$.

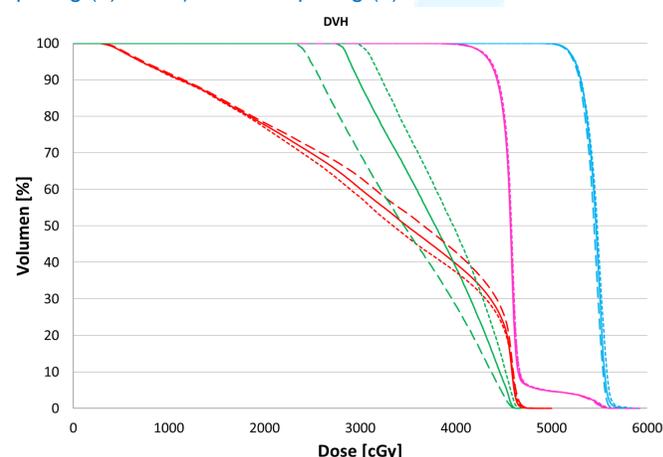
Bowel, bladder and hotspots

Plans	Bowel V45Gy [ccm]		Bladder V35Gy [%]		Hotspot (V107% PTV-Ns*) [%]	
	IMRT	VMAT	IMRT	VMAT	IMRT	VMAT
Non-MCO	-	227 (90-289)	-	57.7 (48.9-67.4)	-	5.38 (4.95-5.55)
MCO (standard)	248 (195-315)	305 (193-600)	63.6 (50.9-69.9)	69.3 (63.6-79.0)	5.18 (4.13-6.08)	1.96 (1.64-2.80)
Sparing relative to non-MCO	-	78	-	11.6	-	-3.42†
MCO (Bowel sparing)	229 (159-269)	312 (174-529)	72.2 (63.4-81.9)	78.8 (75.5-90.3)	5.84 (4.93-6.62)	1.98 (0.84-2.49)
Sparing relative to MCO (standard)	-19	7	8.6	9.5	0.66	0.02
MCO (Bladder sparing)	285 (220-351)	373 (206-577)	44.6 (32.5-56.3)	52.1 (45.0-67.6)	6.08 (5.52-6.69)	2.02 (1.78-2.49)
Sparing relative to MCO (standard)	37	68	-19.0	-17.2	0.90	0.06
Sparing relative to MCO (Bowel sparing)	56	61	-27.6	-26.7	0.24	0.04

All values are medians, numbers in parenthesis are 1st and 3rd interquartile ranges. †A negative value means that the metric in question (in percentages or cubic centimetres) is lower compared to the regimen mentioned. Bold text: Significance at the 1% level (p<0.01) using paired rank tests.



Dose distribution for one female patient in sagittal view showing a) Standard (1), b) Bowel sparing (2) and c) Bladder sparing (3).



DVH for one patient, illustrating the dose to the bowel and bladder for the different dose plans. Turquoise is PTV-T, pink is PTV-N, Green is bladder and red is bowel. Full line: Standard plan (1), dotted line: Bowel sparing plan (2), dashed line: bladder sparing plan (3).