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Development of a decision support tool for optimizing the configuration of the static angle modulated ports

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ABSTRACT

Purpose: To develop a decision support tool for optimizing the configuration of the static angle modulated ports (STAMPs), including the number of ports, gantry angles and collimator angles, using an Eclipse Scripting API (ESAPI) for RapidArc Dynamic (RAD), based on BEV geometric and mechanical constraints, and to evaluate its dosimetric superiority for sinonasal cancer compared with conventional VMAT.

Methods: Treatment plans for 10 patients with sinonasal cancer were retrospectively generated using 3-arcs coplanar VMAT and 1-2 arcs RAD. The prescribed dose was 70 Gy (D50% to PTV70) in 35 fractions. A custom script was developed using ESAPI to generate BEV-based cost map by combining a PTV-fitting term with an OAR-avoidance term for selected OARs. Preferred collimator angles at each gantry position were determined through cost minimization. The optimal configuration of STAMPs was automatically identified at high-cost inflection points where the required collimator rotation exceeded the dynamic limit relative to gantry speed. VMAT and RAD plans were optimized using identical objectives. Plan quality was evaluated using dose-volume metrics, optimization time, estimated delivery time, modulation complexity score (MCS). Statistical comparisons were performed using the Wilcoxon-signed rank test.

Results: The decision support tool automatically selected between 2 and 10 STAMPs per plan according to geometric complexity. Both techniques achieved comparable PTV coverage. Compared with VMAT, RAD plans demonstrated significant reductions in the eyes Dmax (-8%), lenses Dmax (-22%), oral cavity Dmean (-12%) and parotid Dmean (-14%) (p<0.05). The RAD approach also resulted in significant reduction in optimization time (-44%, p<0.001) and estimated delivery time (-34%, p<0.001). The MCS was significantly lower for RAD (0.29±0.02) than for VMAT (0.38±0.04, p<0.001).

Conclusion: The proposed decision support tool successfully determined optimal STAMP configurations without manual trial-and-error. This approach significantly improved OAR sparing and planning efficiency in sinonasal cancer cases, despite using fewer arcs than conventional VMAT.

INTRODUCTION

Background: RapidArc Dynamic (RAD; Varian Medical Systems, Palo Alto, CA) is a novel volumetric modulated arc therapy (VMAT) technique featuring dynamic collimator rotation synchronized with gantry rotation. RAD enables the use of static angle modulated ports (STAMPs), defined by user-selected gantry and collimator angles[1].
However, determination of STAMP configurations currently relies on manual trial-and-error procedures based on planner experience, limiting efficient clinical implementation of this functionality[2].

Purpose: This study aimed to develop an automated decision support tool using the Eclipse Scripting Application Programming Interface (ESAPI) to identify cost-optimized STAMP configurations and to evaluate its clinical utility in head-and-neck cancer planning.

METHODS AND MATERIALS

Patient selection and prescription:
Patient: Ten patients with sinonasal cancer
Prescription: 70 Gy /35 fr to PTV70 (D50% = 70 Gy)
The SIB technique was used to deliver 70 Gy and 63 Gy to PTV70 and PTV63, respectively.

Treatment planning setting and optimization:
For each patient, two treatment plans were generated and compared: conventional VMAT and RAD using the proposed decision-support tool.

- VMAT: 3 coplanar arcs
  collimator angles of 30°, 330°, and 90°.
- RAD: 2 coplanar arcs
  STAMP configurations (the number of STAMPs, gantry and collimator angles) were determined using the proposed ESAPI-based decision support tool.

Algorithm of ESAPI-based decision support tool:
A custom decision-support tool was developed using the ESAPI that generates BEV-based cost maps combining PTV-fit and OAR-avoidance term for user-selected OARs. The workflow consists of three sequential phases:
Phase1: Geometric cost map generation
Phase2: Collimator trajectory optimization
Phase3: STAMP identification.

Plan evaluation metrics:

- Dosimetric evaluateion:
  target: PTV D95%, CTV D95%
  OAR: Dmax to brain stem, lenses, eyes, optic nerves, chiasm, and spinal cord
  Dmean to oral cavity, and parotid glands
- Time: total optimization calculation time
  estimated beam delivery time
- Complexity: monitor unit (MU)
  modulation complexity score (MCS)

Statistical analysis:

- Wilcoxon-signed rank test (p<0.05)

RESULTS

The algorithm determined the optimal collimator angle, shown as a green line in **Figure 1**, by minimizing weighted sum of PTV alignment and OAR overlap costs at each gantry angle. Furthermore, optimal configuration of STAMPs was automatically identified at high-cost inflection points where the required collimator rotation exceeded the dynamic limit relative to gantry speed (indicated by yellow and white markers in **Figure 1**).
As shown in **Table 1**, RAD plan maintained target coverage equivalent to 3-arcs VMAT plans (PTV70 D95%, p=0.63), while providing superior OAR sparing. Specifically, a statistically significant reduction was observed in the Dmax to the eyes (-8%, p=0.002), lens (-22%, p=0.002), and Dmean of oral cavity (-12%, p=0.002) and parotids (-14%, p=0.01) (**Table1**).
The optimization calculation time significantly reduced by approximately 44% (p<0.001) and the estimated delivery time by 34% (p<0.001) compared to the 3-arcs VMAT plans. The MCS was significantly lower for RAD plans (0.29±0.02) than for VMAT (0.38±0.04, p<0.001).

Table 1. Mean value ± standard deviation of plan metrics for VMAT and RAD

Plan metrics		VMAT	RAD	p-value
CTV70	$D_{95\%}$ [Gy]	64.6±3.7	65.0±3.6	0.27
CTV63	$D_{95\%}$ [Gy]	62.4±1.3	62.4±1.1	0.96
PTV70	$D_{95\%}$ [Gy]	60.7±3.7	60.5±4.2	0.63
PTV63	$D_{95\%}$ [Gy]	57.3±1.7	56.8±2.0	0.38
Brain stem	D_{max} [Gy]	43.3±5.9	42.4±4.0	0.42
Eye_L	D_{max} [Gy]	**44.1±6.6**	**40.4±6.0**	**0.002**
Eye_R	D_{max} [Gy]	**41.9±7.5**	**39.6±5.5**	**0.04**
Lens_L	D_{max} [Gy]	**9.9±2.3**	**7.7±1.3**	**0.002**
Lens_R	D_{max} [Gy]	**9.1±2.1**	**8.0±1.5**	**0.002**
Chiasm	D_{max} [Gy]	52.1±1.6	51.3±1.2	0.11
Optic nerve_L	D_{max} [Gy]	53.8±0.8	53.1±0.7	0.07
Optic nerve_R	D_{max} [Gy]	53.4±1.2	53.0±1.5	0.23
Oral cavity	D_{mean} [Gy]	**28.2±13.3**	**24.9±11.5**	**0.002**
Parotid_L	D_{mean} [Gy]	**20.8±9.1**	**18.2±8.3**	**0.01**
Parotid_R	D_{mean} [Gy]	**24.1±12.5**	**20.6±10.6**	**0.01**
Spinal cord	D_{max} [Gy]	25.1±9.1	28.4±10.7	0.14
Optimization time [s]		**244.6±49.6**	**136.0±36.5**	**<0.001**
Est. delivery time [s]		**195.6±0.1**	**129.4±32.5**	**<0.001**
MU		511.9±330.1	652.2±124.3	0.23
MCS		**0.38±0.04**	**0.29±0.02**	**<0.001**

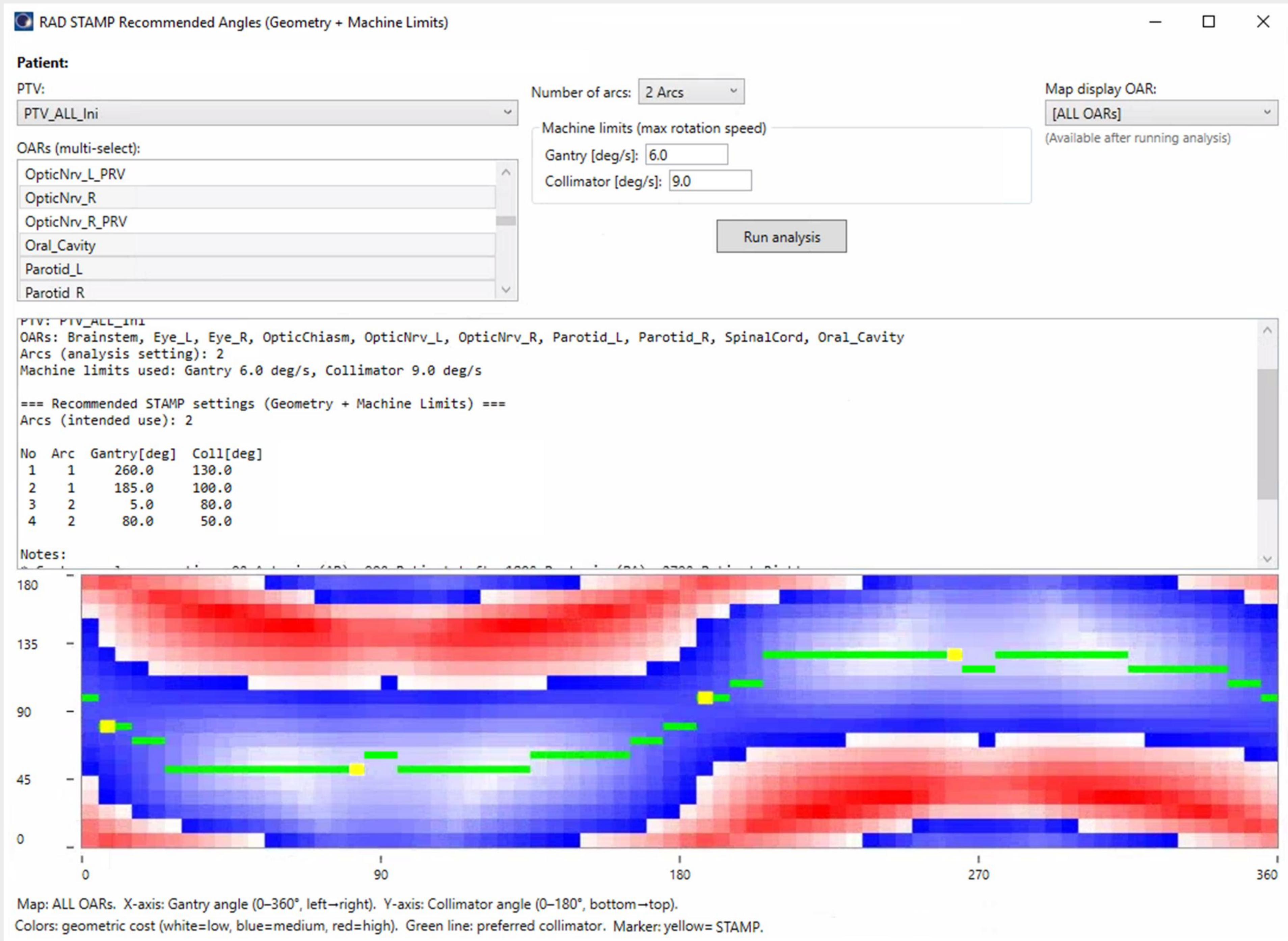

Figure 1. Eclipse Scripting Application Programming Interface showing automated STAMP determination. The ROI map plots gantry (vertical axis) and collimator (horizontal axis) angles, where blue indicates feasible OAR shielding and red indicates ineffective angles. The green line traces the optimal collimator angle, with yellow and white markers indicating the automatically determined STAMP positions.

CONCLUSIONS

The decision support tool successfully determined configuration of STAMPs for RAD without manual trial-and-error. This approach significantly improved OARs sparing and planning efficiency in sinonasal cancer cases, despite utilizing fewer arcs than VMAT.

REFERENCE

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