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A class solution for volumetric-modulated arc therapy planning in postprostatectomy radiotherapy

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ABSTRACT

This study is aimed to test a postprostatectomy volumetric-modulated arc therapy (VMAT) planning class solution. The solution applies to both the progressive resolution optimizer algorithm version 2 (PRO 2) and the algorithm version 3 (PRO 3), addressing the effect of an upgraded algorithm. A total of 10 radical postprostatectomy patients received 68 Gy to 95% of the planning target volume (PTV), which was planned using VMAT. Each case followed a set of planning instructions; including contouring, field setup, and predetermined optimization parameters. Each case was run through both algorithms only once, with no user interaction. Results were averaged and compared against Radiation Therapy Oncology Group (RTOG) 0534 end points. In addition, the clinical target volume (CTV) D_{100}, PTV D_{99}, and PTV mean doses were recorded, along with conformity indices (CIs) (95% and 98%) and the homogeneity index. All cases satisfied PTV D_{95} of 68 Gy and a maximum dose $<$ 74.8 Gy. The average result for the PTV D_{99} was 64.1 Gy for PRO 2 and 62.1 Gy for PRO 3. The average PTV mean dose for PRO 2 was 71.4 Gy and 71.5 Gy for PRO 3. The CTV D_{100} average dose was 67.7 and 68.0 Gy for PRO 2 and PRO 3, respectively. The mean homogeneity index for both algorithms was 0.08. The average 95% CI was 1.17 for PRO 2 and 1.19 for PRO 3. For 98%, the average results were 1.08 and 1.12 for PRO 2 and PRO 3, respectively. All cases for each algorithm met the RTOG organs at risk dose constraints. A successful class solution has been established for prostate bed VMAT radiotherapy regardless of the algorithm used.

Introduction

Published data comparing volumetric-modulated arc therapy (VMAT) with intensity-modulated radiation therapy (IMRT) for pelvic sites indicate equivalent, if not improved, dosimetry and a significant reduction in monitor units and treatment times.[1-5] Despite these results, there is a concern that an increase in planning times will be detrimental to workflow in busy departments.[6]

When presented with a new planning technique or upgraded algorithm there is an unavoidable learning curve that staff must go through. Here the effect of planners' experience will directly affect both the plan time and the quality.[7] The establishment of a class solution serves a number of purposes. It aims to ensure consistency within the department, eases transition periods, and proves to be an invaluable teaching tool when training less experienced staff. In the case of time-consuming VMAT optimization, a class solution also minimizes user interaction and allows for greater productivity.[8] Finally during an algorithm upgrade, testing the solution against an established standard provides valuable quality assurance information when determining the clinical effect of its release.

This study aimed to assess the reliability of a class solution developed for patients receiving radiotherapy following a radical prostatectomy using the VMAT (Varian RapidArc) progressive resolution optimization algorithm version 2 (PRO 2). Plans were assessed based on Radiation Therapy Oncology Group (RTOG) 0534 end points. The same solution was then applied to the PRO algorithm version 3 (PRO 3) to assess the effect of an algorithm upgrade.

Methods and Materials

A total of 10 consecutive patients enrolled on a prospective ethics-approved database were selected for this study. The clinical target volume (CTV) was

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Table 1
Definition of volumes used in optimization

Structure	Definition
VMAT PTV	Margin added to PTV: 0 mm superior/inferior and 1 mm left/right/anterior/posterior Excludes CTV and rectum
VMAT CTV	0 mm margin added to CTV
VMAT rectum in	Area of rectum within VMAT PTV
VMAT rectum out	Remaining rectum outside VMAT PTV
VMAT bladder	Bladder outside VMAT PTV with a 2-mm gap between structures
VMAT ring tunning volume	20-mm wide ring with a 5-mm gap between all other structures

contoured according to published consensus guidelines[9] and divided into inferior and superior segments as defined by the pubic symphysis. To create the planning target volume (PTV), the inferior CTV and the superior CTV were expanded by 8 and 10 mm, respectively, in all directions, except anteriorly where the expansion was 15 mm. This differential expansion circumvents potential increased interfraction motion above the pubic symphysis owing to variations in bladder and rectal filling.[10] A bulk homogeneity correction was applied to the entire bladder to correct for the presence of contrast. The rectum was contoured from the level of the rectosigmoid junction to the level of the ischial tuberosities as a solid structure. The femoral heads were contoured inferiorly to the level of ischial tuberosities. The small bowel was not contoured as it did not encroach on the treatment fields.

Dose prescription and organ at risk dose constraints

All plans were prescribed to receive 68 Gy to 95% of the PTV (D_{95}) at 2 Gy per fraction. The PTV and organs at risk (OARs) planning goals were taken from RTOG 0534. These goals are as follows: PTV 2 cm^3 maximum dose $<$ 78.2 Gy, rectal $V_{40} <$ 55% and $<$ 35% for V_{65}, bladder $V_{40} <$ 70% and $<$ 50% for V_{65}, and femoral head $V_{50} <$ 10%.[11]

Planning

A junior dosimetrist (C.L.) with no IMRT or VMAT experience was responsible for planning all cases. A set of instructions was followed that included contouring (Table 1), field setup, and predetermined optimization parameters (Table 2). A visual representation of these planning volumes and their relationship to each other is displayed in the Fig. The establishment of these instructions was based on a 12-month implementation phase of VMAT into our clinical department. This included research, clinical experience, and input from our medical physicists, dosimetrists, radiation therapists, and radiation oncologists. Each case was run through PRO 2 once and then applied to a new optimization algorithm, PRO 3; thereby, testing the integrity of the class solution to an updated algorithm and also benchmarking it against an existing, clinically used optimization process. This was a retrospective study, and, as such, the plans achieved here were not used for clinical treatment. Plans were produced using Varian Eclipse treatment planning system V10 and calculated using the anisotropic analytical algorithm V10.0.28.

Field setup

Each case consisted of 2 full arcs (180.1° to 179.9° and 179.9° to 180.1°). The collimator was set at a fixed position of 0° (25° for field 1 and 325° for field 2). The isocenter was placed in the geometric center of the PTV; this margin was considered sufficient given that the PTV was fully exposed at each treatment degree. The variable dose rate was set to a maximum of 600 MU/min.

Optimization

As the field size, isocenter, and collimator angle were manually set, the geometric optimizer option was not used. There was no limit placed on the monitor units, and, as such, the monitor unit objective function was not used. The normal tissue objective (NTO) was activated to aid protection of undefined healthy tissue. Based on the results of previous VMAT planning study for postprostatectomy patients, predetermined input values for each optimization structure and the NTO were used. These values included percentage volume, dose limits, and priorities placed on each structure (Table 2).

Progressive resolution optimizer algorithm version 2

The progressive resolution optimizer is a unique algorithm used in VMAT planning with the Eclipse treatment planning system. This algorithm allows for the dynamic multileaf collimator file to be generated, along with variation in gantry speed and dose rate at the time of optimization. In PRO 2, the optimization is separated into 5 multiresolution levels. At each level, additional control points are introduced; hence, gradually refining the result.[12] As such, each level may be used to manipulate different aspects of the planning objectives. The earlier level may be more conducive to accepting changes related to the OARs; however, the latter 2 levels focus on target coverage. For this study, all objectives were entered before the commencement of level 1, and no action was taken at any of the subsequent 4 levels.

Progressive resolution optimizer algorithm version 3

The PRO 3 algorithm consists of 4 multiresolution levels. All 178 control points are used in all levels rather than the progressive increase in control point used in PRO 2. The use of all control points from the beginning of the optimization process allows PRO 3 to estimate an achievable dose distribution earlier than PRO 2. An internal logic has also been added forcing the system to choose less complex dynamic patterns, when presented with multiple equivalent solutions. PRO 3 also has the addition of the intermediate dose calculation; however, this was not used in the investigation of the class solution, as the pelvic region does not contain large regions of significant heterogeneity. A more in-depth description of these algorithms has been published by Vanetti *et al.*[13]

Table 2
Optimization input parameters

Structure	Objective	Volume	Structure dose (Gy)	Priority
CTV prostate bed	Upper	0%	70	250
CTV prostate bed	Lower	100%	69	220
VMAT PTV	Upper	0%	70	250
VMAT PTV	Upper	0%	70	250
VMAT PTV	Lower	100%	69	220
VMAT rectum in	Upper	0%	69.5	250
VMAT rectum in	Lower	100%	68	140
VMAT rectum out	Upper	26%	3	140
VMAT rectum out	Upper	12%	7	150
VMAT rectum out	Upper	3%	15	110
VMAT bladder	Upper	35%	5	110
VMAT bladder	Upper	12%	10	110
VMAT bladder	Upper	0%	70.5	200
VMAT ring TV	Upper	0%	34	90
Normal tissue objective parameters	Distance from structure	1 cm		
	Upper	105%		
	Lower	40%		
	Gradient	0.2		
	Priority	190		

TV = tuning volume.