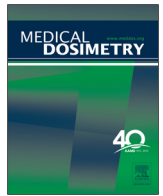




# Medical Dosimetry

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Dosimetry Contribution:

## Improving plan quality for prostate volumetric-modulated arc therapy

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### ARTICLE INFO

#### Article history:

Received 29 December 2016

Received in revised form 16 March 2017

Accepted 3 July 2017

#### Keywords:

Prostate  
VMAT  
Optimization  
Quality assurance

### ABSTRACT

We critically evaluated the quality and consistency of volumetric-modulated arc therapy (VMAT) prostate planning at a single institution to quantify objective measures for plan quality and establish clear guidelines for plan evaluation and quality assurance. A retrospective analysis was conducted on 34 plans generated on the Pinnacle<sup>3</sup> version 9.4 and 9.8 treatment planning system to deliver 78 Gy in 39 fractions to the prostate only using VMAT. Data were collected on contoured structure volumes, overlaps and expansions, planning target volume (PTV) and organs at risk volumes and relationship, dose volume histogram, plan conformity, plan homogeneity, low-dose wash, and beam parameters. Standard descriptive statistics were used to describe the data. Despite a standardized planning protocol, we found variability was present in all steps of the planning process. Deviations from protocol contours by radiation oncologists and radiation therapists occurred in 12% and 50% of cases, respectively, and the number of optimization parameters ranged from 12 to 27 (median 17). This contributed to conflicts within the optimization process reflected by the mean composite objective value of 0.07 (range 0.01 to 0.44). Methods used to control low-intermediate dose wash were inconsistent. At the PTV rectum interface, the dose-gradient distance from the 74.1 Gy to 40 Gy isodose ranged from 0.6 cm to 2.0 cm (median 1.0 cm). Increasing collimator angle was associated with a decrease in monitor units and a single full 6 MV arc was sufficient for the majority of plans. A significant relationship was found between clinical target volume-rectum distance and rectal tolerances achieved. A linear relationship was determined between the PTV volume and volume of 40 Gy isodose. Objective values and composite objective values were useful in determining plan quality. Anatomic geometry and overlap of structures has a measurable impact on the plan quality achieved for prostate patients being treated with VMAT. By evaluating multiple planning variables, we have been able to determine

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<http://dx.doi.org/10.1016/j.meddos.2017.07.001>

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important factors influencing plan quality and develop predictive models for quality metrics that have been incorporated into our new protocol and will be tested and refined in future studies.

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## Introduction

Volumetric-modulated arc therapy (VMAT) is an inverse planned, highly conformal radiotherapy technique that has become standard practice in the treatment of prostate cancer. In comparison to 3-dimensional conformal radiotherapy and fixed-field intensity modulated radiotherapy, VMAT allows a more efficient delivery of high-quality plans and the potential to provide more uniform target doses and improved normal tissue sparing.<sup>1-3</sup>

VMAT plans can be complicated and time-consuming due to the multiple target prescription aims, surrounding organs at risk (OARs) constraints, and variable patient anatomy. Departments use standardized sets of target coverage and OAR tolerance goals which should be achievable for the majority of patients; however, stricter constraints may be achievable in many cases and, in others, anatomic variations necessitate early identification of a need for prioritizing objectives. Without clear evidence-based goals, it can be difficult for the planner to determine when greater sparing of surrounding tissues can be achieved without compromising target coverage.<sup>4</sup> Decision making can be subjective and remains dependant on the skill, knowledge, and experience of the evaluator. Quality assurance should be conducted on every plan and requires an objective decision using quantitative knowledge of what can be achieved for a particular plan with individual anatomy.<sup>5</sup>

There are limited data in the literature looking at a holistic evaluation of the dosimetry of VMAT prostate planning, with reported studies indicating that patient-specific factors and differences in treatment planning system (TPS) and optimization parameters may affect plan quality.<sup>6,7</sup>

Pinnacle TPS (Philips Medical Systems, Fitchburg, WI) was implemented in our department in 2013, and a departmental protocol for prostate VMAT planning was developed. This study was part of a quality improvement exercise that critically evaluated our planning strategy. We sought to quantify inconsistencies in planning, develop objective measures for plan quality, and establish clear guidelines for plan evaluation and quality assurance with the aim of developing a more standardized and consistent approach to prostate VMAT dosimetry in our department.

## Methods and Materials

### *Ethical considerations*

Institutional ethics board exemption was obtained for this project.

### *Patient selection*

Thirty-four plans, clinically treated between January 2014 and November 2015, were selected for retrospective analysis. Each plan had a prescription dose (PD) of 78 Gy in 39 fractions to the prostate only using a VMAT technique. Patients with hip prosthesis were excluded. Patients were treated using image-guided radiotherapy and fiducials. Patients were diagnosed with T1c through to T2c, N0, and M0.

### *Plan construction*

Dosimetry was calculated on noncontrast-enhanced computed tomography (CT) (2 mm slice thickness). A high-definition CT scan was also acquired through the region of interest to facilitate more precise delineation of targets and OAR. Patients were supine with standard stabilization equipment for the head, knee, and feet support (CIVCO Medical Solutions, Kalona, IA). All patients adhered to the departmental bowel and bladder protocol. Patients are asked to empty their bladder and drink 500 mL of water 40 minutes before CT scanning. An enema is used only when rectum is insufficiently empty (> 3 cm dimension antero-posterior).

The radiation oncologist (RO) contoured the clinical target volume (CTV), planning target volume (PTV), rectum, and bladder (whole organs) according to the Australian and New Zealand Faculty of Radiation Oncology Genito-Urinary 2010 consensus guidelines.<sup>8</sup> The radiation therapist (RT) contoured the femurs and additional structures required for plan optimization purposes ([Appendix A1](#)).

All plans were calculated using a 0.25-mm dose grid on Pinnacle<sup>3</sup> versions 9.4 and 9.8 (Philips Medical Systems) with the collapsed cone convolution algorithm. Plans were calculated on 1 of 2 beam models: an Elekta Axesse (4-mm multileaf collimator beam modulator) or an Elekta Agility (5-mm multileaf collimator) SmartArc (Elekta, Stockholm, Sweden). The following parameters were used: constrain leaf motion, 0.46 cm/degree, final gantry spacing of 4, and maximum delivery time of 90 seconds. The majority of plans used a convolution dose and maximum number of iterations of 20 and 40, respectively.

### *Data collection*

Plan quality was evaluated using the following parameters: dose volume histograms (DVH) analysis of targets and OAR, PTV and OAR volumes and relationships, plan conform-

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