Medical Dosimetry ■■ (2017) ■■–■■

Medical Dosimetry

journal homepage: www.meddos.org

Dosimetry Contribution:

Evaluation of a commercial automatic treatment planning system for prostate cancers

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ARTICLE INFO

Article history:
Received 25 November 2016
Received in revised form 1 March 2017
Accepted 29 March 2017

Keywords:
Automated planning optimization
Prostate cancer
Plan quality
Interoperator variation

ABSTRACT

Recent developments in Radiation Oncology treatment planning have led to the development of software packages that facilitate automated intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) planning. Such solutions include site-specific modules, plan library methods, and algorithm-based methods. In this study, the plan quality for prostate cancer generated by the Auto-Planning module of the Pinnacle^3 radiation therapy treatment planning system (v9.10, Fitchburg, WI) is retrospectively evaluated. The Auto-Planning module of Pinnacle^3 uses a progressive optimization algorithm. Twenty-three prostate cancer cases, which had previously been planned and treated without lymph node irradiation, were replanned using the Auto-Planning module. Dose distributions were statistically compared with those of manual planning by the paired t-test at 5% significance level. Auto-Planning was performed without any manual intervention. Planning target volume (PTV) dose and dose to rectum were comparable between Auto-Planning and manual planning. The former, however, significantly reduced the dose to the bladder and femurs. Regression analysis was performed to examine the correlation between volume overlap between bladder and PTV divided by the total bladder volume and resultant V70. The findings showed that manual planning typically exhibits a logistic way for dose constraint, whereas Auto-Planning shows a more linear tendency. By calculating the Akaike information criterion (AIC) to validate the statistical model, a reduction of interoperator variation in Auto-Planning was shown. We showed that, for prostate cancer, the Auto-Planning module provided plans that are better than or comparable with those of manual planning. By comparing our results with those previously reported for head and neck cancer treatment, we recommend the homogeneous plan quality generated by the Auto-Planning module, which exhibits less dependence on anatomic complexity.

***PACS number*:** 87.55.de.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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http://dx.doi.org/10.1016/j.meddos.2017.03.004

Introduction

Treatment planning is time-consuming, and the quality of the outcome depends on the method followed by each planner.[1,2] This has been a long-standing problem in radiation therapy. Plan optimization is performed so as to minimize the objective function.[3] The optimization process can be schematically compared to a kinetic process of a ball rolling on a curved surface. In general, the objective function has a complicated structure. Therefore, it is very difficult to know a priori the location of the minimum of the corresponding curved surface.[4] In most cases, that minimum tends to deviate from the planning goal composed by several clinical dose constraints. Redefining the objective function multiple times for the minimum point to be properly led to the clinical goal is complex and each additional optimization increases the total planning time. Furthermore, even within the goal, there exists a large variety of dose distributions.[5] The criterion of when the optimization should be stopped depends on each planner's judgment. In this sense, severe interoperator variation does exist regarding the final outcome. The use of automated planning with simple input as the clinical goal would decrease interoperator variability in modern radiation therapy.[6]

In January 2015, the Auto-Planning module was released with the Pinnacle[3] treatment planning system (v9.10, Philips Medical Systems, Fitchburg, WI). Auto-Planning successfully automated the consecutive multiple sequence optimization process using progressive optimization.[7] Each optimization sequence is followed by quantitative evaluation and fine-tuning of the objective function. The automated optimization process reduces the total time required to generate a treatment plan. Furthermore, the initial outcome generated by Auto-Planning satisfies most of the clinical goal, effectively reducing interoperator variation.

The efficiency brought about by Auto-Planning seems apparent.[8] Therefore, the quantitative evaluation of its plan quality in the dose distributions becomes an important subject. Auto-Planning generates several planning structures: rings, hot and cold spot regions of interest (ROIs), residual structures, and other special ROIs to spare organs at risk (OARs). These automatically generated structures allow Auto-Planning to better dose control in terms of target coverage and OARs sparing.

In this study, we evaluated the plan quality of Auto-Planning for prostate cancer cases in comparison with clinically delivered manual planning. By examining the correlation between volume overlap between OARs and target and resultant doses, we quantitatively showed a reduction of interoperator variation in Auto-Planning. The comparative evaluation has already been performed for head and neck cancer treatment plans.[8-10] The prostate region and the head and neck regions have different anatomic complexities. By comparing our results with those for head and neck, we report a homogeneous plan quality generated by the Auto-Planning module, with less dependence on anatomic complexity.

Methods and Materials

To evaluate the plan quality of Auto-Planning, we re-planned 23 previously delivered clinical prostate IMRT treatment plans. The gross tumor volume (GTV) was equal to the intact prostate. The clinical target volume was equal to (1) GTV for the low-risk group, (2) GTV and the basal part of the seminal vesicle for the intermediate-risk group, and (3) GTV and the whole part of the seminal vesicle for the high-risk group. The 23 patients were randomly chosen irrespective of the risk factors. Accordingly, there were 2 patients in the low-risk group, 11 in the intermediate-risk group, and 10 in the high-risk group. Patients in the low-risk group were mainly treated by surgery in the University of Tokyo Hospital. Therefore, the number in the low-risk group became less than those in other groups by randomly sampling the patient data from the radiation therapy department database. The planning target volume (PTV) consisted of the clinical target volume with a setup margin of 4 mm in the posterior direction and 5 mm in all other directions. The prescription dose for PTV was set to 76 Gy in 38 treatment fractions, with a coverage that dose to 95% of PTV was equal to 76 Gy by following References 11 and 12. All plans were delivered using single-beam VMAT on a Synergy system equipped with the Agility multileaf collimator (Elekta AB, Stockholm, Sweden). Each of the manual plans was created by a planner who was randomly selected from 6 medical physicists. Each plan strictly followed the University of Tokyo Hospital guidelines imposing the following clinical dose constraints: V40 < 60%, V65 < 30%, and V70 < 15% for rectum and bladder and D_{max} < 55 Gy for femurs, taking into account the research result on a late toxicity after IMRT for prostate cancers.[12] These plans were clinically delivered within 1.5 years before this study.

Regarding the Auto-Planning module, the beam parameters and optimization goals formulated by dose constraints can be prepared as a protocol in the "Treatment Technique" interface. We compiled an appropriate single protocol from iterative test runs for 3 pilot patients (1 in intermediate risk and 2 in high risk), and applied it to the 23 patients of our study (see Appendix A for the adopted optimization goal). The initial results of the Auto-Planning module were not followed by further manual intervention. All of the delineations of PTV and OARs as well as the position of the isocenter of each plan were shared between Auto-Planning and manual planning. To compare the results between Auto-Planning and manual planning, we performed a paired t-test at 5% significance level.