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Medical Physics Contribution:

Dosimetric benefits of automation in the treatment of lower thoracic esophageal cancer: Is manual planning still an alternative option?

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A B S T R A C T

This study aimed to design automated volumetric-modulated arc therapy (VMAT) plans in Pinnacle auto-planning and compare it with manual plans for patients with lower thoracic esophageal cancer (EC). Thirty patients with lower thoracic EC were randomly selected for replanning VMAT plans using auto-planning in Pinnacle treatment planning system (TPS) version 9.10. Historical plans of these patients were then compared. Dose-volume histogram (DVH) statistics, dose uniformity, and dose homogeneity were analyzed to evaluate treatment plans. Auto-planning was superior in terms of conformity index (CI) and homogeneity index (HI) for planning target volume (PTV), significantly improving 8.2% ($p = 0.013$) and 25% ($p = 0.007$) compared with manual planning, respectively, and decreasing dose of heart and liver irradiated by 20 to 40 Gy and 5 to 30 Gy, respectively ($p < 0.05$). Meanwhile, auto-planning further reduced the maximum dose (D_{max}) of spinal cord by 6.9 Gy compared with manual planning ($p = 0.000$). Additionally, manual planning showed the significantly lower low-dose volume (V_5) for the lung ($p = 0.005$). For auto-planning, the V_5 of the lung was significantly associated with the relative volume index (the volume ratio of PTV to the lung), and the correlation coefficient (R) and p-value were 0.994 and 0.000. Pinnacle auto-planning achieved superior target conformity and homogeneity and similar target coverage compared with historical manual planning. Most of organs at risk (OARs) sparing was significantly improved by auto-planning except for the V_5 of the lung, and the low dose distribution was highly associated with PTV volume and lung volume in auto-planning.

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Introduction

Current manual planning seems to be a time-consuming and cumbersome method. The planner needs to have profound experience about characteristics of treatment planning system and anatomic configurations of targets and organs at risk (OARs). Intensity-modulated radiotherapy (IMRT) and volumetric-modulated arc therapy (VMAT) are an inverse planning process that optimize the dose distribution for every set of fields according to the chosen dose-volume histogram (DVH) objective. Meanwhile, most optimization systems require the user to specify goals,

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normally in the form of DVH or biological objectives, each with a specific priority. However, the DVH objectives guided to balance the target volume and OARs are often unknown before treatment planning for specific patients. Consequently, the quality of IMRT or VMAT plans heavily relies on the personal experience of planners and the time they can allocate to a specific plan.

Auto-planning algorithms thus were developed to improve the overall treatment plan quality and decrease the time of required planning.[1,2] Auto-planning relates an iterative algorithm-based approach to automatically adapt objectives, constraints, and dose-shaping contours during the optimization process to achieve clinical goals. But there are arguments about automated radiation therapy treatment planning replacing experienced manual planning in the next 10 years.[3] Therefore, it is necessary to compare and verify the quality of treatment plans generated by auto-planning approach against those made by experienced manual planners.

The goal of this work is to evaluate the effectiveness of auto-planning compared with historical manual plans in patients with lower thoracic esophageal cancer (EC). Meanwhile, the comparison would be performed to judge which treatment approach is more appropriate in terms of lower thoracic EC. All the investigation was executed in the arena of VMAT in Pinnacle treatment planning system (TPS).

Methods and Materials

Patient selection and ethics approval

Thirty patients with lower thoracic EC were randomly selected from a database at Hangzhou Cancer Hospital. Ethical approval for the retrospective study was obtained from the institute's ethical committee. Manual VMAT plans designed in Pinnacle TPS version 9.20 (Philips, Medical System, Fitchburg, WI) were approved and used for clinical treatment of each patient, and the characteristics of all patients are listed in Table 1. All approved treatment plans were regarded as reference objects in this research.

Historical manual plans

The historical plans were designed by experienced dosimetric planners and accepted by clinical radiation oncologists for patient treatment. All patients were treated with VMAT technique using a single full arc (182° to 178°) with the collimator rotation set to 20°. The treated plans were manually optimized for a 10-MV photon accelerator (Axesse, Elekta, Sweden). The target volume objective functions and OAR constraints were shown in Table 2 as the specification in our institution. The optimization of required accepted plans is a repetitive process. For example, the planner may compensate the prescription dose for lack of target volume or reduce the high dose in normal tissues or target volume. If the initial plan is of poor quality, the designed objectives and constraints are needed to be adjusted and replanned until it is acceptable to both the radiation physicist and the oncologist.

Table 1
Clinical features of 45 patients with lower thoracic EC

Characteristics	Number of cases (%)
Sex	
Male	24 (80)
Female	6 (20)
Age	
>60	10 (33.3)
40-60	15 (51.1)
<40	5 (15.6)
Length (cm)	
>8	7 (24.4)
4-8	17 (55.6)
<4	6 (20)
PTV (cc)	
>400	9 (28.9)
300-400	18 (60)
<300	3 (11.1)
Lung (cc)	
>4000	6 (20)
3000-4000	12 (40)
2000-3000	12 (40)

Replanned using auto-planning optimization

Auto-planning optimizer is an iterative module in Pinnacle TPS version 9.10. The previous steps are similar to manual planning for designing the VMAT plans. The planners need to create the dose constrains around the target volume called the "ring" and set the beam geometry using a single full arc with collimator rotation for lower thoracic EC. Auto-planning algorithms are also based on the objective functions. The prescription dose was given to the planning target volume (PTV)

Table 2
Objective functions of manual plan for PTV and OARs

Structure	Constraint	Priority
PTV	Max dose < 63 Gy	80
	Min dose > 59 Gy	90
	Min DVH V_{60} > 96%	90
	Max DVH V_{63} < 1%	50
Lung	Max DVH V5 < 45%	30
	Max DVH V20 < 25%	30
	Max DVH V30 < 16%	30
	Max EUD < 12 Gy	30
Heart	Max DVH V30 < 30%	30
	Mean dose < 25 Gy	30
Liver	Max DVH V5 < 65%	20
	Max DVH V20 < 30%	20
	Mean dose < 23 Gy	20
Spinal cord	Max dose < 45 Gy	30

EUD, equivalent uniform dose.

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