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Study for reducing lung dose of upper thoracic esophageal cancer radiotherapy by auto-planning: volumetric-modulated arc therapy *vs* intensity-modulated radiation therapy

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ABSTRACT

This study aimed to investigate the dosimetric differences and lung sparing between volumetric-modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT) in the treatment of upper thoracic esophageal cancer with T3N0M0 for preoperative radiotherapy by auto-planning (AP). Sixteen patient cases diagnosed with upper thoracic esophageal cancer T3N0M0 for preoperative radiotherapy were retrospectively studied, and 3 plans were generated for each patient: full arc VMAT AP plan with double arcs, partial arc VMAT AP plan with 6 partial arcs, and conventional IMRT AP plan. A simultaneous integrated boost with 2 levels was planned in all patients. Target coverage, organ at risk sparing, treatment parameters including monitor units and treatment time (TT) were evaluated. Wilcoxon signed-rank test was used to check for significant differences ($p < 0.05$) between datasets. VMAT plans (pVMAT and fVMAT) significantly reduced total lung volume treated above 20 Gy (V_{20}), 25 Gy (V_{25}), 30 Gy (V_{30}), 35 Gy (V_{35}), 40 Gy (V_{40}), and without increasing the value of V_{10}, V_{13}, and V_{15}. For V_5 of total lung value, pVMAT was similar to aIMRT, and it was better than fVMAT. Both pVMAT and fVMAT improved the target dose coverage and significantly decreased maximum dose for the spinal cord, monitor unit, and TT. No significant difference was observed with respect to V_{10} and V_{15} of body. VMAT AP plan was a good option for treating upper thoracic esophageal cancer with T3N0M0, especially partial arc VMAT AP plan. It had the potential to effectively reduce lung dose in a shorter TT and with superior target coverage and dose homogeneity.

Introduction

An estimated 455,800 new esophageal cancer cases and 400,200 deaths occurred in 2012 worldwide.[1] At present, it is one of the most common malignant diseases in China. Radiotherapy is a major treatment method for esophageal carcinoma as more than 60% of the patients who are

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diagnosed have their carcinomas at an advanced stage, which cannot be resected.[2]

Treatment options for radiotherapy include 3-dimensional conformal radiation therapy (3D-CRT), intensity-modulated radiation therapy (IMRT), and volumetric-modulated arc therapy (VMAT). Compared with 3D-CRT, many studies reported that IMRT had better dose coverage to the target and better organ at risk (OAR) sparing over 3D-CRT.[3-5] Over the past few years, with the development of computer software and improvement of linear accelerator, a special form of IMRT called VMAT, combining the advantage of fixed-IMRT and arc delivery, has been introduced to radiotherapy for more than a decade. Now it is a standard technique for radiotherapy. With dynamic multileaf collimator motion, variable gantry speed modulation and dose rate, VMAT not only could produce similar or better dose distributions than IMRT, but also could achieve a reduction in treatment time (TT) and monitor unit (MU).[6-9] Decreasing TT could reduce patient discomfort and intrafraction variation during the treatment, and less MUs could decrease radiation of OARs and minimize side effects, including radiation pneumonia.[10] Gao *et al.*[9] and Wu *et al.*[11] reported that VMAT had better target coverage over IMRT plan and significantly reduced spread of high doses to the lung and mean lung dose (MLD), but the result also indicated that gantry continuous rotation in VMAT increased the volume of low-dose irradiation to lung. Increased exposure to radiation of the V_5, $V_{10,}$ and V_{13} of lung may lead to increased risk of radiation pneumonitis (RP).[12]

Recently, a prototype version of the auto-planning module became clinically available, which uses an iterative algorithm-based approach to automatically adapt objectives, constraints, and dose shaping contours during the optimization process. Automatic planning automatically adds and adjusts individual optimization goals, constraints, and weights; thus, it reduces the total time of generating a treatment plan. Also, the initial optimization outcome satisfies most of the clinical goal, effectively reducing the variation of operator intervention. Several studies showed similar or superior plan quality in the planning target volume (PTV) coverage, but a significant reduction in dose to OAR between AP plan and clinical manual plan, which indicated the technique parameters used in the study, was biased toward normal tissue sparing relative to manual plan.[13-16] Up to now, automatic plan has been mainly applied to head and neck cancer and rectal cancer, whereas those for upper thoracic esophageal cancer have yet to be reported.

In this study, we evaluated VMAT plan and conventional IMRT plan for upper thoracic esophageal cancer patients with staging T3N0M0 for preoperative radiotherapy by auto-planning technique to evaluate the target coverage and normal tissue sparing, especially lung sparing. MU and TT required were also compared.

Materials and Methods

Patient selection and contouring

There were 391 esophageal cancer patients treated from April 2015 and November 2016 at our department. We selected 16 patients diagnosed with upper thoracic esophageal cancer T3N0M0 according to the 2010 Union for International Cancer Control/American Joint Committee on Cancer staging system for preoperative radiotherapy. The patient characteristics are listed in Table 1.

Patients were simulated and treated in supine position in a head and neck/upper thoracic thermoplastic mask with their arms placed alongside the body. All of the computed tomography (CT) images were acquired on an MX4000 Dual CT Scanner System (Philips Medical Systems, Shenyang, China). The CT images ranged from C3 to the lower edge of the liver including the whole lung. The CT data of each patient were transferred to the Pinnacle^3 treatment planning system v9.10 (Philips Healthy, Fitchburg, WI).

Combing the CT images, esophageal radiography, esophageal endoscopy, and clinical examinations, the gross tumor volume (GTV) encompassed the esophageal tumor, and clinical target volume (CTV) was defined as GTV area plus mediastinal lymph nodes and bilateral supraclavicular lymph node. PTV_{63} was formed by expanding the GTV by 5 mm in all directions. $PTV_{50.4}$ was CTV plus a margin of 5 mm superiorly, inferiorly, and circumferentially excluding the volume outside the body. Appropriate margin change of PTV_{63} and $PTV_{50.4}$ was made based on the actual patient breathing mobility. In our department, the standard prescription

Table 1
Patient characteristics (n = 16)

Age (years)	
Median	61
Range	49-68
Sex	
Male	13
Female	3
TNM stage	
T3N0M0	16
GTV volume (cm^3)	
Median	41.9
Range	16.5-58.4
PTV1 volume (cm^3)	
Median	121.6
Range	82.6-159.9
PTV2 volume (cm^3)	
Median	518.3
Range	369.1-676.2
Total Lung volume (cm^3)	
Median	3138.9
Range	2192.6-4492.5