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A primary study on setting the limit ring in intensity-modulated radiation therapy treatment planning in lung cancer

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▸ ***Technical note***

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ABSTRACT

Background: The influence of the limit ring on the final dose distribution in the design of the lung cancer intensity-modulated radiation therapy (IMRT) plan was studied. ***Materials and Methods:*** A total of 20 patients with lung cancer in 2017 were selected. Seven radiation beams were designed for each patient, and the limit ring width (RW) was set at 0.6, 0.8, 1.0, and 1.2 cm, respectively. The distance between the inner diameter of the limit ring and the target area (RD) was set 0.6, 0.8, 1.0, and 1.2 cm, respectively. The other parameters used in the plan were set at the same position. In addition, the conformity index (CI) and homogeneity index (HI) were calculated, and normal tissues were assessed. ***Results:*** Under the condition of the same number of radiation beams and the same distance between the limit ring and the target area, the smaller the limit ring, the better the CI of the target area and the less the HI of the target area. When the size of the limit ring was set the same, the closer the limit ring was to the target area, the better the CI of the dose in the target area, and the less the HI of the target area. ***Conclusions:*** In central lung cancer, when the target volume is approximately 800 cc, the optimal dose distribution is obtained when the RW is set at 0.8 cm and the RD is set at 0.6 cm.

Keywords: *Lung cancer, IMRT, limit ring, CI, HI.*

INTRODUCTION

In recent years, more and more people die of lung cancer due to its high morbidity and mortality [1-5]. Radiotherapy is a major means of treatment for patients with non-small cell lung cancer (NSCLC). For every 1 Gy prescription dose increase, the tumor local control rate (TCP) is increased by 1%, and the 3- to 5-year mortality is decreased by 3%. For small cell lung cancer, the 2- to 3-year survival rate is increased by 5% [6].

But, unreasonable dose distribution in the treatment can cause pulmonary injury, reducing the life quality of patients. A relevant meta-analysis showed that a total of 836 NSCLC patients with synchronous chemoradiotherapy had an incidence of symptomatic radioactive pneumonia of 29.8%, whereas that of 65-year-olds was 50% [7].

Therefore, how to obtain a more reasonable dose distribution while increasing the Tumor Control Probability (TCP) and reducing the Normal Tissue Complication Probability (NTCP) has gradually become a major issue in the radiation therapy of lung cancer [8-17].

Previous efforts have been made to improve target dose, such as dosimetric comparison between different kinds of radiation types [1,2], different numbers of beams [4], different kinds of energy, [16] and so on.

But the influence of the limit ring used during planning on the dose distribution remains unclear.

In this study, the influence of the limit ring on the dose distribution of the radiotherapy intensity-modulated radiation therapy (IMRT) plan was investigated, and the research can broaden people's understanding of the parameters used in radiotherapy planning, help people get a better dose distribution, and improve the tumor cure rate.

MATERIALS AND METHODS

Clinical data

Twenty patients with lung cancer admitted to our hospital from January to November 2016 were selected as the study subjects, including 12 men and 8 women, aged 50 to 70 years, with an average age of 53±0.2 years (men, 56±0.3; women, 51±0.5). The patients had different degrees of progressive dyspnea symptoms. All the patients were diagnosed with squamous cell carcinoma by pathological examination, and all elected to undergo radiation therapy.

Method

Positioning

All patients were in the supine position, lying on the flat plate, with their hands folded around foreheads, legs stretched naturally, and chest fixed with a thermoplastic shell. Enhanced computed tomography (CT) scanning was performed on patients under a calm breathing condition using a large-aperture CT scanner produced by Philips in the Netherlands. The thickness of the layer was 5 mm. The scanning range was from neck to lower edge of the lung.

Target definition

All the targets were delineated by professional radiotherapy physicians in reference to ICRU report No. 50 62.

The gross target volume (GTV) included the clinical and radiographic tumor range. The clinical target volume (CTV) was put out by GTV, with 8 mm to the lungs and 5 mm to the side of the metastatic lymph nodes. The planning target volume (PTV) includes the CTV plus the range of organ movement and the positioning error. At the same time, it was obtained by a CTV external release of 8 mm. When the anatomical barrier is included, an appropriate adjustment should be made. The organs at risk (OAR) were the spinal cord, heart, and lung. The tumor volume in this study was 812±40 cc (men 822±50 cc, women 801±30 cc).

The prescription dose (the lowest dose segmentation of 95% PTV, with 30 fractions) was 60 Gy. The current study was approved by the medical ethics committee of The Center Hospital of QingHe. The registration number is 20180001 (registration date 2018.7.7).

Settings

Using the XIO treatment planning system (CMS), the dose rate was 400 MU/min. For each patient, we designed seven radiation beams respectively. We designed RW 0.6, 0.8, 1.0, and 1.2 cm respectively. The RD were 0.6, 0.8, 1.0, and 1.2 cm, respectively, for each IMRT plan. For the larger RD, we set the smaller limit parameters. When RD was 0.6 cm, the maximum dose of the ring was set at 5400 cGy; for 0.8 cm, the maximum dose of the ring was set at 5200 cGy; for 1.0 cm, the maximum dose of the ring was set at 5000 cGy; and for 1.2 cm, the maximum dose of the ring was set at 4800 cGy. Each plan satisfied the individual clinical requirements. In this experiment, we had a total of 320 plans.

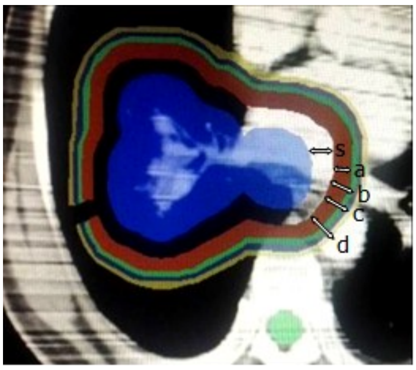

Figure 1. The blue region in the center of image shows PTV. The rings around show limit ring for constrain the dose distribution. RD is 0.6 cm (s) and RW is 0.6 cm (a, the red region), 0.8 cm (b, include a and the green region), 1.0 cm (c, include b and the blue region), and 1.2 cm (d, include c and the yellow region) respectively.

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The program assesses and analyzes the dose-volume histogram (DVH) and compares the target conformity index (CI) and the homogeneity index (HI).

The CI calculation formula of the target area is as equation (1):

$$CI= (V_T-V_{Ref}/V_T) \times (V_T-V_{Ref}/V_{Ref}) \quad (1)$$

where V_{Ref} represents the plan target zone volume covering 95% of the prescription dose and V_T represents the planning target volume, and V_{Ref} covers 95% of the prescription dose. The volume of the CI value is 0 to 1; the closer to 1, the better the target CI.

(2) The calculation formula of target area HI is as equation (2)

$$HI = D_{5\%}/D_{95\%} \quad (2)$$

$D_{5\%}$ and $D_{95\%}$ represent the dose that covers 5% and 95% volume of the PTV, respectively. The closer the HI value is to 1, the more uniform the dose distribution.

Statistical method

The data were statistically analyzed by SPSS 20.0 software. In the results, the measurement data were expressed as mean ± standard deviation (x ± s), and t test was used for comparison between data sets. P<0.05 was statistically significant.

Table 1. Normal tissue organ dose constraints

OAR	Dose constraints
Lung	V_{30} < 18% ; V_{20} < 28% ; $Mean_{dose}$ < 1300
Cord	$Mean_{dose}$ < 45 Gy
Heart	V_{40} < 30% ; V_{30} < 40% ; $Mean_{dose}$ < 30 Gy

V20 = volume of lung receiving 20 Gy dose, V30 = volume of lung receiving 30 Gy dose, V40 = volume of lung receiving 40 Gy dose.

RESULTS

Comparison of target area volume of patients

As shown in figure 2, when the number of external radiation beam was 7, the RD was 0.6 cm and 0.8 cm, the CI and HI of the plans were relatively stable. When the RD was 0.8 cm, compared with 0.6 cm, the CI is increased, and the HI is also increased. When the RD was 1.0 cm and 1.2 cm, the CI and HI of the planned target area changed greatly.

We can also see that the CI and HI of the target increased when the RW increased in the curves RD 0.6 and RD 0.8.

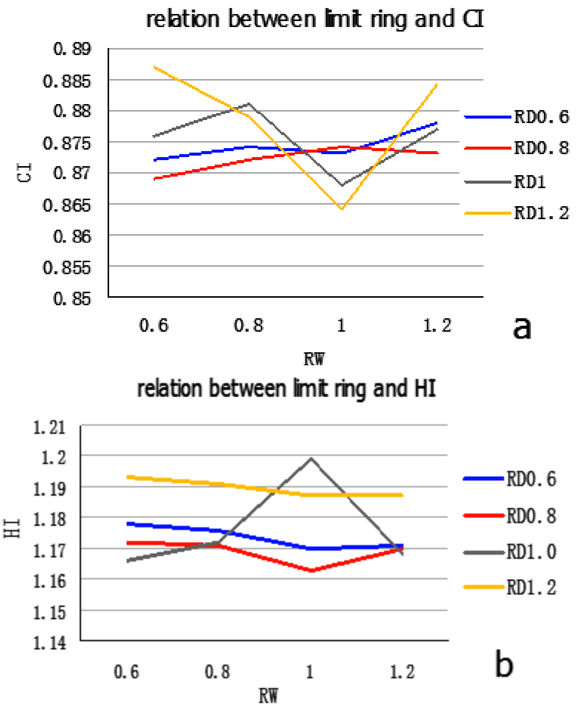

Figure 2. Relation between the limit ring and CI **(a)** HI **(b)**. The closer to 1, the better the CI, HI we got.

Comparison of the normal tissue volume of patients

As shown in figure 3, V_5, V_{20}, and V_{30} decreased with the larger RW. And, at the same time, V_5 and V_{20} of the plan are optimal at RD 0.6, and then RD 0.8. But for V_{30}, RD 0.8 is the better choice.

As for spinal cord and heart of all the participants, there was no significant difference

(P = 0.041 and P = 0.033, respectively).

Whereas the change of RD and RW did show a significant difference between the groups (P = 0.618 and P = 0.726, respectively).

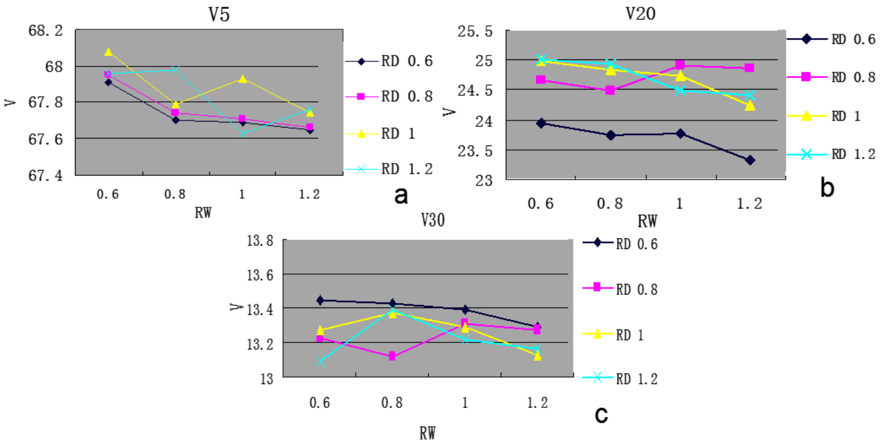

Figure 3. Relation between RD, RW, and V5 **(a)**, V20 **(b)**, V30 **(c)**.The smaller the V5, V20, and V30, the better the protection of lung.

DISCUSSION

Unreasonable dose distribution during lung cancer treatment may cause lung injury such as radiation pneumonia. A study found that there are many factors influencing the dose distribution during the treatment of lung cancer: Fan Lin believed that the planning algorithms of different planning systems may overestimate the target dose and underestimate the lung dose volume, which may affect the judgment of clinicians [15]. Different energies of radiation therapy and different radiation field parameters can influence the dose distribution [16]. At the same time, a positioning error in the treatment process will affect the final dose distribution, which will affect the therapeutic effect [5]. Different definitions of lung volume in the delineation of target area of non-lung cancer affect the influence of normal lung dosimetry size on the parameters of lung dosimetry [17]. And, respiratory movement also will affect the distribution of dose [14].

Our study found that when 95% of the volume of the target area received the prescribed dose, RW will affect the HI of the target area. When the RW is 0.6 cm and the RD is 1.2 cm, the CI of the target area will get the best result, but the HI will be reduced.

When the RW is 1.0 cm and the RD is 0.8 cm, the HI of the target area was the best result. In addition, with the increase of the ring distance, the range of variation of target uniformity was also large, and the more unstable the change was. As the ring distance increases, the uniformity of the target area decreases. The optimal value is obtained when the RD is 0.8 cm.

It is also necessary to further study the relationship between other parameters and the CI and HI of the target, to grasp the best fitness and uniformity and obtain the best dose distribution.

CONCLUSION

In central lung cancer, when the target volume is approximately 800 cc, the RD is 0.6 cm, and the optimal dose distribution is obtained when the RW is 0.8 cm.

In short, in the process of lung cancer intensity-modulated plan design, under the condition of the guaranteed real time demand, choosing appropriate parameters of program calculation not only saves design time, it can effectively improve the quality of the plan.

Conflicts of interest**:** *Declared none.*

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