Helical tomotherapy optimized planning parameters for nasopharyngeal cancer

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Abstract. Helical TomoTherapy (HT) planning depends on optimize parameters including field width (FW), pitch factor (PF) and modulation factor (MF). These optimize parameters are effect to quality of plans and treatment time. The aim of this study was to find the optimized parameters which compromise between plan quality and treatment times. Six nasopharyngeal cancer patients were used. For each patient data set, 18 treatment plans consisted of different optimize parameters combination (FW=5.0, 2.5, 1.0 cm; PF=0.43, 0.287, 0.215; MF=2.0, 3.0) were created. The identical optimization procedure followed ICRU83 recommendations. The average D50 of both parotid glands and treatment times per fraction were compared for all plans. The study show treatment plan with FW1.0 cm showed the lowest average D50 of both parotid glands. The treatment time increased inversely to FW. The FW1.0 cm the average treatment time was 4 times longer than FW5.0 cm. PF was very little influence on the average D50 of both parotid glands. Finally, MF increased from 2.0 to 3.0 the average D50 of both parotid glands was slightly decreased. However, the average treatment time was increased 22.28%. For routine nasopharyngeal cancer patients with HT, we suggest the planning optimization parameters consist of FW=5.0 cm, PF=0.43 and MF=2.0.

1. Introduction

The nasopharynx, a cuboidal chamber, is located below the base of skull and behind of the nasal cavity [1]. Radiation therapy oncology group (RTOG 0225) suggested that the intensity modulated radiotherapy (IMRT) combine with chemotherapy is suitable treatment for staging I-IVB squamous cell carcinoma of nasopharynx [2].

The helical tomotherapy (HT) is a specialized technique of delivering IMRT by using a 6 MV linear accelerator mount on the ring gantry that rotate around the patient while couch through the gantry. The HT treatment planning parameters including; Field width (FW), pitch factor (PF) and modulation factor (MF).

The FW has three setting values 1.0, 2.5 and 5.0 cm. The chosen FW is compromised between treatment time and dose distribution in superior-inferior direction. Although a smaller FW results in good dose distribution in superior-inferior direction, there are increased treatment times [3].The PF is the couch distance travel for one gantry rotation divided by FW. Kissick et al. have recommend the solution to use PF of 0.86/n, where n is an integer. For reduce dose fluctuation due to helical junction of divergent beam in HT as known as “Thread effect” [4].

MF defines as the ratio of maximum leaf open time to the average leaf open time. Increasing MF contributes the larger of beam modulation. However, there are increased treatment times [4].
This study aim to find the optimize parameters of Helical TomoTherapy treatment planning for nasopharyngeal cancer concerning quality and efficiency of the treatment plan.

2. Material and methods

2.1. Patients data
The CT images and structure contour data of six nasopharyngeal cancer patients that had been treated with HT were randomly selected. Each patient data set, three planning target volumes (PTV) were defined as PTV70, PTV59.4 and PTV54. All plans were created using a dose per fraction of 1.8 Gy.

2.2. Treatment planning
For each patient data set, 18 treatment plans were created with different combination of treatment planning parameters FW=1.0, 2.5 and 5.0 cm. PF=0.43, 0.287 and 0.215 MF= 2.0 and 3.0. The initial parameters set used for planning were FW=5.0, PF=0.43 and MF=2.0. These initial planning parameters set was combined with all optimization dose constraints in Table1, as default plan. This plan was 250 iterations optimized; under the dose constraint to PTV followed ICRU83 recommendation. The dose homogeneous in PTV was maintained between V95% less than 2% volumes and V107% less than 2% volumes. The maximum and minimum penalty for PTV was changed during 250 iterations until the dose to PTV fulfilled the ICRU83 recommendations. All plans were optimized base on single dose constraint in PTV.

Table 1. Optimization dose constraints for all the treatment plan.

| Name      | overlap priority | block | importance | max dose | max dose penalty | DVH volume | DVH dose | min dose penalty |
|-----------|------------------|-------|------------|----------|------------------|------------|----------|------------------|
| PTV 70    | 1                | -     | 150        | 70.5     | 150              | 95         | 69.5     | 140              |
| PTV59.4   | 4                | -     | 1          | 70       | 1                | 95         | 59.4     | 1                |
| PTV59.4-ex| 2                | -     | 90         | 69       | 170              | 95         | 59.8     | 100              |
| PTV 54    | 3                | -     | 100        | 55.5     | 60               | 95         | 54.5     | 95               |

2.3. Plan evaluation
All plans were evaluated using the 50% dose of both parotid glands volume (D50) and treatment times. The statistical result of both parotid glands D50 and treatment times were analyzed using SPSS statistics version 17.0. The student pair t-test was used to compare treatment times and the Wilcoxon test was performed to compare D50 of both parotid glands.

3. Results

3.1 D50 both parotid glands
The average of D50 of both parotid glands for all patients data set with different treatment planning parameters combination, total 108 treatment plans were generated. There were no significantly different of D50 of both parotid glands. But the average of D50 of both parotid glands show the lowest when the FW=1.0 cm was used to combine with other optimize parameters.

The figure 2 show average of D50 of the all patient parotid glands with the different optimize parameter. The average of D50 of all parotid glands using FW 5.0, 2.5 and 1.0 cm. were 28.21, 25.83 and 24.61 Gy, respectively. Treatment plans using PF 0.43, 0.287 and 0.215, the average of D50 of all parotid glands were 26.60, 26.18 and 25.87 Gy, respectively. Treatment plan using MF 2.0, 3.0, the average of D50 of all parotid glands were 26.78 Gy, 25.65 respectively. FW demonstrate the major effect to D50 of the parotid glands compare to PF and MF.

3.2. Treatment time per fraction
The average of treatment time per fraction with 3 combination planning parameter showed in figure 3. Treatment plan with FW=5.0, PF=0.43, MF=2.0 showed the significantly lowest treatment time as 3.23±0.33 minutes when compare with other group except with FW=5.0, PF=0.43, MF=3.0 group.

The average of treatment time per fraction with different planning parameters showed in figure 4. Average treatment time when used FW 5.0, 2.5 and 1.0 cm. showed 4.51, 8.39 and 19.37 minutes, which
was 4 times longer than the FW5.0 cm. Average treatment time of PF 0.43, 0.287 and 0.215 showed 9.57, 10.10 and 12.21 minutes. Decreasing PF from 0.43 to 0.215 the average treatment time was significantly increased 18.97%. Finally increasing the MF from 2.0 to 3.0 the average treatment time was significantly increased about 3 minutes.

**Figure 3.** The average treatment times per fraction for all patients data set with different treatment planning parameters combination.

**Figure 4.** The average treatment times per fraction with different optimize parameters.

### 4. Discussions

This work investigates the optimized planning parameter in HT for nasopharyngeal cancer. Finding of this work are consistent with Vicent Wu *et al.* that reported the FW effect on the quality of treatment plan in the OAR dose, but not so much on the PTV. Increasing FW was reducing the effectiveness in OAR sparing. When decreasing the PF from 0.43 to 0.215, there was little influence on D50 of both parotid glands [5]. J Lee Roy reported that decreasing PF from 0.43 to 0.287 slight improve dose distribution in PTV, but not significantly reduce the dose to OAR. We increased the MF from 2.0 to 3.0, the average D50 of both parotid glands were slightly decreased 4.2%. Ryczkoski A sustainable recommended the value of MF 1.8-3.0 for head and neck HT planning. However, if it is necessary to reduce the dose in OAR he suggested the MF should not be lower than 2.4 [6].
Our study, the FW had a larger effect on D50 of both parotid glands than PF and MF was consistent with Skorska M et al. that they show FW was mainly parameter in dose distribution because FW had effect on dose fall off in longitudinal direction when used the large FW demonstrated the large penumbra. The dose distribution was slightly influence when PF increased from 0.215 to 0.43 [7].

The FW had the major effect on treatment time. Using the FW 1.0 cm. we received the average longest treatment time 19.05±3.58 minutes which was 4 times longer than used the FW 5.0 cm. Therefore, the treatment time is inversely proportional to the FW consistent with previous studied. Monica M. et al. reported treatment times ranged from 22-27, 8-12 and 4-6 minutes for the FW1.0, 2.5 and 5.0 respectively [8]. The PF parameter was less effect to treatment time than FW and MF which was consistent with Woch et al. that they reported the treatment times decreasing with larger PF value [9]. However, Monica M. et al. found that increasing the PF value only marginally influenced treatment times because might be complexity of target volume or which force the HT system to adjust other machine parameter such as gantry period [8]. This effect treatment times to maintain treatment planning object. The last optimize parameter, when increasing the MF from 2.0 to 3.0 the average treatment time was increased 22.28%. Ryczkoski et al. reported that the treatment time was approximately linear correlation decrease when reduce the MF range 6.0 to 3.0. They found treatment plan with the MF value below 3.0 the treatment time was not shortened. This was related of the maximum speed of machine gantry [6]. For our HT system version 4.0, the minimum gantry rotation period is 12 sec [10]. This allows the treatment time to be shortened to an MF about 2.5.

5. Conclusions
We had analysed 18 treatment plans with different combination of optimize parameters for nasopharyngeal carcinoma by concerning target dose constraint follow ICRU83 recommendation. Treatment plan consist of FW=5.0 cm, PF=0.43 and MF=2.0 show the optimal compromised between plan quality and efficiency treatment time. These optimize parameters may serve as routinely guideline for nasopharyngeal carcinoma treatment planning with HT system.

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