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Effect of Intensity Level on Dose in Intensity-modulated Radiotherapy for Nasopharyngeal Carcinoma

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Keywords: Nasopharyngeal Carcinoma; intensity-modulated radiotherapy; intensity level; the total number of segments; monitor units

Abstract: To make intensity-modulated radiotherapy (IMRT) planning for nasopharyngeal carcinoma based on XIO planning system through adjusting values of intensity level, and provide a basis for the selection of the value of intensity level. 30 patients with nasopharyngeal carcinoma were randomly enrolled. Eight IMRT plans were made for each case using ELEKTA XIO 4.64 TPS, with the application of 7evenly distributed fixed incidence directions (153, 102, 51, 0, 309, 258, 207), a minimum segment length of 2cm and a minimum sub-field monitor units (MUs) of 5 MU.All plans were optimized with intensity levels from 20 to 5 respectively, using SWO tool to optimize sub-field weight. The dose-volume histogram was used to evaluate the dose distribution in target volume (PTV) and organs at risk (OAR). With the level value decreasing from 20 to 5, the total number of segments of IMRT plans was decreased from(186±16) to(58±7)(F=352.4, P<0.001). All plans ranged from 20 to 7 were no significant dosimetry differences on parameters of PTV and OAR (P>0.05) through comparing between any two plans, but the number of segments was reduced to (87±6). Using ELEKTA XIO treatment planning system to make IMRT plan for nasopharyngeal Carcinoma, the plan can still reach requirement for clinical dose with intensity level 7, and there is a significant reduction in the total number of segments.

1. Introduction

Since nasopharyngeal carcinoma has been proved to be a dose-dependent tumor [1, 2], Radiologists have never stopped studying the use of increased doses to improve local control.Compared with conformal radiotherapy, IMRT makes the shape of high dose area and target area highly conformable, greatly improves the conformability and dose uniformity of target area, reduces the irradiated volume of critical organs, reduces adverse reaction of normal tissues, and improves the quality of life of patients in the later stage[3]. However, IMRT technology brings large total field number and MUs, and longer treatment time, which has a certain influence on the treatment effect [4], and will increase radiotherapy wear of the machine [5]. Therefore, it is of great significance to reducethe total number of segments and MUs in the static intensity modulation technique to shorten the treatment time. In this study, the purpose is to use the XIO planning system to design static IMRT plans for nasopharyngeal carcinoma with different intensity level, and to find the optimal level that can meet the needs of clinical treatment with less total subfields and short treatment time.

2. Data and methods

2.1 General Information

Thirty cases with nasopharyngeal carcinoma (NPC) received radical radiotherapy were randomly enrolled from our department, including 19 males and 11 females, aged 35 to 73 years (median 48 years). According to the 8th edition of AJCC, 4 patients were stage I, 7 stage II, 13 stage III and 6 stage IVa.

2.2 Method

2.2.1 CT simulator positioning

The patients were in supine position with their hands on both sides of the body, and head-neckshoulder thermoplastic film was used for postural fixation. The reconstruction slice thickness of CT scan is 3mm, and the scanning range is from the top of skull to 5cm below the clavicle. The image is transferred to CMS XIO 4.64 planning system for image import.

2.2.2 Prescription dose and planning design

The target area is contoured on CT according to ICRU No. 50 and 62. The prescription dose of PGTVnx was 2.10～2.25 Gy per fraction, and the total dose was 66～76 Gy. PGTVnd was 2.00～2.25 Gy per fraction and the total dose was 66～70 Gy.PCTV1 was 1.80～2.05 Gy per fraction,and the total dose was 60～62 Gy.PCTV2 and PCTVnd was 1.7～1.8 Gy per fraction, and the total dose was 50～56 Gy. Program Requirements:(1) <20% of the volume of the PTV receiving ≥110% of the prescribed dose; (2) PTV receives <5% of the volume of ≥115% of the prescribed dose; (3) PTV received <93% of the prescribed dose volume <1%. Refer to 2010 Expert Consensus on Guidance on Target Area and Dose Design of Intensity Modulated Radiotherapy for Nasopharyngeal Carcinoma [6]. Eight IMRT plans were designed for each case according to the prescription and critical machine limit given by the doctor. The gantry angles were 153°, 102°, 51°, 0°, 309°, 258°, and 207°, respectively. The minimum side length of the sub-field was set as 2cm, and the intensity level was selected as 20~5. The sub-field weight was optimized with SWO optimization tool, and the minimum sub-field MU was set as 5MU.

2.2.3 Evaluation of IMRT plan

Dose-volume histogram (DVH) was used to evaluate IMRT plan.(1)the total number of segments and MUs;(2)D95%, Conformal index(CI), homogeneity index(HI) of PTV; (3) organs at risk(OAR) :The maximum dose (Dmax) of brain stem, spinal cord, optic chiasm, optic nerve and lens, and D30%, D40% and average dose (Dmean) of mandible, temporomandibular joint, parotid gland and oropharynx. where Dx% represents the exposure dose to x% of the target volume. Conformability index (CI) is used to evaluate the coincidence between the isodose line (surface) and the target volume,the calculation formula is:

$CI = \frac{V_{T,\,\mathrm{ref}}}{V_T} \times \frac{V_{T,\,\mathrm{ref}}}{V_{ref}}$ [7] among them,VT is the target volume; Vref is the volume covered by the prescription isodose line; VT, ref is the target volume covered by the prescription isodose line. The closer the CI value is to 1, the higher the conformity. Uniformity index (HI) is used to evaluate the uniformity of dose distribution in the target area:

$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}}$, the closer the HI value is to 0, the better the uniformity[8].

2.3 Statistical Methods

The statistical software SPSS20.0 was used for statistical description and inference. The quantitative data were expressed by $\bar{\chi}$ ±s. The linear mixed model was used for the comparison among different intensity level. The pairwise comparison of the parameters among the intensity leve was conducted with Tukey test. The test level α = 0.05. When *P* < 0.05, the difference was considered to be statistically significant.

3. Results

3.1 The total number of segments and MUs of IMRT plans

The total number of segments was different between each group of IMRT plan(*F*=352.4, *P*<0.001). The total number of segments decreased from (186±16) to (58±7) as the level value decreased from 20 to 5. There was no statistical difference in MUs among the different plans (*F*=0.64, *P*>0.05). See Table 1 for details.

Table 1: Comparison of the total number of segments and MUs with different level values($\bar{\chi}$ ±s)

Level	number of segments	MU
20	186±16	987±72
17	162±18**(20)**	972±69
15	145±17**(20-10)**	969±64
13	132±15**(20-9)**	984±56
11	118±12**(20-8)**	979±54
9	105±11**(20-7)**	963±47
7	89±15**(20-6)**	974±49
5	63.00±4.00**(20-4)**	969±47
F	352.4	0.64

Pour: (a-b indicates that the level value is in a comparison between each group and the current group *P*=0.018-*P*<0.001

3.2 Effect of intensity level on target dose distribution

Table 2: Comparison of parameters such as D95% and HI, CI of target area with different level values ($\bar{\chi}$ ±s)

Level	PGTVnx	PGTVnd	PCTV1	PCTV2	PCTVnd	HI	CI
20	6969±88	6966±110	6325±107	5447±225	5145±59	0.10±0.01	0.82±0.02
17	6978±82	6958±89	6338±101	5438±218	5131±47	0.10±0.01	0.82±0.03
15	6961±79	6962±97	6329±89	5436±236	5127±67	0.10±0.01	0.82±0.03
13	6959±89	6959±92	6332±108	5428±198	5129±39	0.10±0.01	0.82±0.03
11	6971±68	6951±102	6321±98	5432±167	5118±56	0.10±0.01	0.82±0.04
9	6976±76	6959±108	6319±110	5429±189	5119±59	0.10±0.01	0.82±0.03
7	6961±67	6948±96	6316±102	5417±223	5109±49	0.10±0.01	0.82±0.03
5	6789±45**(20-5)**	6808±113**(20-5)**	6078±112	5189±267**(20-5)**	4787±67**(20-5)**	0.25±0.01**(20-5)**	0.69±0.04**(20-5)**
F	2.56	110.82	78.89	157.82	123.89	82.73	63.7
P: price	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Pour: (a-b) indicates that the level value is in a comparison between each group and the current group P=0.022-P<0.001

There are differences among the evaluation parameter groups of target areas among IMRT plans with different intensity level (F=5.21~100.78, P<0.001).The D95%, CI, HI of PTV in level 5 was significantly lower than that in group 20~7 (P=0.08~P <0.001) and cannot meet the clinical requirements; All the evaluation parameters of the target area were similar between 20 and 7 (P>0.05), and could meet the clinical requirements. See Table 2 for details.

3.3 The effect of intensity level on the dose of OARs

The evaluation parameters of IMRT were different among the IMRTs (F=3.14~26.72, P<0.001). Parotid Dmean at level 5 was higher than that in group 20~7 (P=0.001). The Dmax of spinal cord was different between level 5 and 15~7 (P=0.002~P<0.001). It was significantly higher than that of 20~7 groups (P<0.001). Dmean, D40%, Dmax, Dmax of optic nerve and brain stem of mandible, temporomandibular joint, Dmean and Dmax of temporomandibular joint were significantly different from those of 20~9 groups when level was 5 (P=0.012~<0.001). However, there was no significant difference in all OAR parameters between the groups at level 20~7 (P>0.05).

4. Discussion

Because of the complex anatomical site of nasopharyngeal carcinoma and sensitivity to radiotherapy and chemotherapy, radiotherapy alone or combined chemotherapy has become the most important treatment for nasopharyngeal carcinoma[9]. Compared with conventional radiotherapy, intensity-modulated radiotherapy can increase the dose of tumor target area and reduce the radiation dose of surrounding normal tissues. However, due to the large number of total segments, the large number of MU, and the large number of missed shots between MLC leaves, the uncertainty of patient displacement probability and target dose in a single treatment may be increased[10]. When using the static intensity modulation (step&shot) mode to make the intensity modulation radiotherapy plan, the higher the intensity level is adopted, the more the total number of segments is generated, and the number of generated small MUs is correspondingly increased. Zhu Junqiang [11] showed that for static IMRT, the higher the intensity level, the more the number of segments and the longer the treatment time. The number of segments and the intensity level have a linear relationship. Therefore, it is necessary to reasonably select the intensity level in clinical application. Chi Zifeng [10]reported that the more the number of segments in IMRT plan, the larger the dose deviation. It is suggested that the total number ofsegments in IMRT plan should be controlled at 80 less than. Dai Liyan[12] found in the preliminary study on the influence of intensity modulated radiotherapy planning design parameters on the dose verification results that the existence of small subfields can affect the dose distribution, and the smaller the segments, the more easily affected by mechanical accuracy. The increase of the number of small fields will cause the error of single point dose, which is a direct factor affecting the pass rate of plane dose γ verification. The total number of segments in the intensity modulation plan is affected by the optimization algorithm and the setting of optimization parameters. During the optimization of the intensity modulation plan, the optimization tool shall be reasonably used to set the optimization parameters, and the number of segemnt and the number of MUs shall be reduced as far as possible without affecting the intensity modulation dose. Cao Yankun[13]used Pinnacle treatment planning system to make esophageal cancer IMRT plan ,When the intensity level was reduced from 12 to 8 ,the total segments was reduced by 17%, and the total MUs is basically unchanged.

The analysis of the above results showed that the intensity level decreased gradually from 20 to 5, and the total number of segments decreased from 186 ±16 to 58 ±7. When the level value was between 20 and 7, the tumor target area and OAR of each IMRT plan could meet the clinical requirements, and there was no difference in the parameters of PTV and OAR between the two groups.

To sum up, all IMRT planned target areas and OAR evaluation parameters with intensity level between 20 and 7 can meet the clinical treatment needs, and there is no difference between the two groups, but the number ofsegemnts is significantly reduced when the level value is 7. Therefore, the reasonable reduction of intensity level can effectively reduce the total number of subfields, shorten the treatment time, reduce the movement of patients during treatment, increase the biological effect of treatment and reduce the wear of the machine.

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