*Original Article*

# Dosimetry Comparison between Volumetric Modulated Arc Therapy with RapidArc and Fixed Field Dynamic IMRT for Local-Regionally Advanced Nasopharyngeal Carcinoma

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## ABSTRACT

**Objective**: A dosimetric study was performed to evaluate the performance of volumetric modulated arc radiotherapy with RapidArc on locally advanced nasopharyngeal carcinoma (NPC).

**Methods:** The CT scan data sets of 20 patients of locally advanced NPC were selected randomly. The plans were managed using volumetric modulated arc with RapidArc and fixed nine-field coplanar dynamic intensity-modulated radiotherapy (IMRT) for these patients. The dosimetry of the planning target volumes (PTV), the organs at risk (OARs) and the healthy tissue were evaluated. The dose prescription was set to 70 Gy to the primary tumor and 60 Gy to the clinical target volumes (CTV) in 33 fractions. Each fraction applied daily, five fractions per week. The monitor unit (MU) values and the delivery time were scored to evaluate the expected treatment efficiency.

**Results:** Both techniques had reached clinical treatment's requirement. The mean dose ($D_{mean}$), maximum dose ($D_{max}$) and minimum dose ($D_{min}$) in RapidArc and fixed field IMRT for PTV were 68.4±0.6 Gy, 74.8±0.9 Gy and 56.8±1.1 Gy; and 67.6±0.6 Gy, 73.8±0.4 Gy and 57.5±0.6 Gy ($P$<0.05), respectively. Homogeneity index was 78.85±1.29 in RapidArc and 80.34±0.54 ($P$<0.05) in IMRT. The conformity index (CI: 95%) was 0.78±0.01 for both techniques ($P$>0.05). Compared to IMRT, RapidArc allowed a reduction of $D_{mean}$ to the brain stem, mandible and optic nerves of 14.1% ($P$<0.05), 5.6% ($P$<0.05) and 12.2% ($P$<0.05), respectively. For the healthy tissue and the whole absorbed dose, $D_{mean}$ of RapidArc was reduced by 3.6% ($P$<0.05), and 3.7% ($P$<0.05), respectively. The $D_{mean}$ to the parotids, the spinal cord and the lens had no statistical difference among them. The mean MU values of RapidArc and IMRT were 550 and 1,379. The mean treatment time of RapidArc and IMRT was 165 s and 447 s. Compared to IMRT, the delivery time and the MU values of RapidArc were reduced by 63% and 60%, respectively.

**Conclusion:** For locally advanced NPC, both RapidArc and IMRT reached the clinic requirement. The target volume coverage was similar for the different techniques. The RapidArc technique showed some improvements in OARs and other tissue sparing while using reduced MUs and delivery time.

**Key words:** Volumetric modulated arc therapy; Intensity-modulated radiotherapy; Dosimetry; Target volume; Nasopharyngeal carcinoma

## INTRODUCTION

Recently, nasopharyngeal carcinoma (NPC) patients more likely have received intensity-modulated radiotherapy (IMRT) than three dimensionals' conformal radiotherapy (3D-CRT). The IMRT has got better dose distribution in target volume and lower dose for organs at risk (OARs), especially for the parotids[1-3]. But IMRT needs complex plan management, more fixed fields and monitor units (MUs) especially for NPC which has large target volume, more OARs and more overlapping of target volume. All of the above may bring the prolonging of the treatment time (for example, 7–9 fixed-field dynamic IMRT needs about 7–10 minutes of treatment delivery) which may cause the increasing of the movement of the swallowing and the position shift during the treatment, so that the clinical efficacy may be reduced consequently.

Generally, the number of the fixed fields can increase the freedom of the plan management, and the development of the volumetric modulated arc therapy

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technique brings the design of the treatment plan to a new stage which can produce various optimization methods based on the differences of the peak value optimization[4]. Nowadays, RapidArc was developed mainly by the optimization of the multi-leaf collimators shape, the change of the dose rate delivery and the rotation of the gantry[5-8]. It was based on the volumetric modulated arc therapy technique and can obtain the similar distribution of the fixed IMRT. The analytical anisotropic algorithm (AAA) system was used for dose calculation[9], and GLAaS[10] and PTW-729[11] methods were applied for quality control to ensure the accuracy and security in the clinical application[12].

Currently, multiple centers compared the dose distribution of the both techniques and generally suggested that volumetric modulated arc therapy with RapidArc was a rapid, safe and accurate radiotherapy technique for many tumors like gliomas, brain metastases and some lung tumors according to the preliminary results[13-17].

NPC needs large and complex target volume and has many OARs around, so that complicated fields' management was necessary. Therefore, in this study, RapidArc was compared at the reference of the fixed 9-field IMRT in dosimetry for locally advanced NPC.

## MATERIALS AND METHODS

### Patients' Characteristics

Twenty cases of location CT scan data (layer 3 mm) was randomly selected from the locally advanced NPC patients who had received radiotherapy (RT) continuously in Radiotherapy Department, Beijing Cancer Hospital. The patients' characteristics are shown in Table 1, and the clinical stage was according to the Stage of NPC (AJCC 2002) followed as below. Among these 20 patients, three patients had been diagnosed as T4 and six patients as N3. The gross tumor volume (GTV) was ranged from 51.4 $cm^3$ to 421.8 $cm^3$ and the median volume was 130.9±83.2 $cm^3$.

**Table 1.** Patients' General and Clinical Characteristics

| Parameters (20 cases) | Values |
|---|---|
| Age (y) | 48 (23–70) |
| Sex (male:female) | 7:3 |
| Stage III | 13 |
| Stage IV | 7 |

### Treatment Plan Management

Two treatment plans were performed for each patient. RapidArc was compared to the fixed 9-field coplanar dynamic IMRT in dosimetry. The Eclipse system from the Varian Company (Denver, USA) was used for the two RT plans, with 6MV-X ray and 120 multi-leaf collimator in it. Considering the large target volume of the locally advanced NPC and complex OARs around, the double-arc plan was adopted for RapidArc and the coplanar fixed 9-field plan was selected for IMRT. Meantime, the AAA 8.6 edition system was applied for calculation.

The simultaneous boost plan was used and the dose prescribed as: GTV 70 Gy/33f, 95% planning target volume (PTV) 60 Gy/33f was generated by 5-mm outer margin of clinical target volume (CTV) and 5 mm apart from the skin at least.

The quality control of the plan was in accordance with the standard dose-volume histogram (DVH) of $D_{98\%}$ and $D_{2\%}$ which represent the doses of 98% and 2% PTV and they indicated the minimum and maximum doses of the plan respectively. The conformity index (CI) of the target volume is expressed as $CI_{95\%}=(PTV_{60Gy}/V_{PTV})\times(PTV_{60Gy}/V_{60Gy})$[18]. $PTV_{60Gy}$ represents the volume receiving the prescription dose 60 Gy in the target volume, $V_{PTV}$ stands for the volume of the PTV, $V_{60Gy}$ is in the name of the volume which has received the prescribed dose. The homogeneity index (HI) of the target volume is defined as $HI=100\times[1-(D_{5\%}-D_{95\%})/D_{mean}]$[15]. OARs, $D_{33\%}$, $D_{mean}$ , $D_{50\%}$, and $D_{66\%}$ were adopted to evaluate the dose distribution of both sides of the parotids. $D_{mean}$ and $D_{max}$ (the maximum dose which was defined as the dose received by less than 2 ml volume of the following OARs) were applied to evaluate the dose of the lens, spinal cord, mandible and optic nerves. For the healthy tissue, integrity absorption dose (DoseInt) was used as the evaluation standard accompanied by $D_{mean}$ and $V_{10Gy}$ at the same time. The time interval of the treatment delivery and the MU values of the techniques were also compared.

### Statistical Analyses

The SPSS 13.0 (SPSS Inc., IL, USA) was applied for statistical data management and analysis, and double-side *t*-test was employed to compare the difference between two treatment plans at statistically significant level of $P<0.05$. The null hypothesis of no difference in dosimetry between study groups was tested with the use of the log-rank test at a two-sided level of significance of 0.05. Confidence intervals were calculated and study groups were compared by means of the log-rank test. All other hypothesis tests were two-sided at a significance level of 0.05.

## RESULTS

### Dosimetry Analysis of Target Volume

Table 2 shows the comparison of the dose distribution of the PTVs and the CI and HI of the target volumes. According to the clinical requirement, $D_{mean}$ and $D_{max}$ of the PTV were lower while $D_{min}$ was slightly higher and statistically significant for IMRT. The $CI_{95\%}$ of RapidArc and IMRT were both 0.78±0.07 ($P>0.05$). However, the HI for RapidArc and IMRT were 78.9±1.3 and 80.4±0.5, respectively ($P<0.05$).

### Dosimetry Comparison of OARs and Healthy Tissues

Table 3 manifests the dose comparison of the OARs for the two plans. As we can see, the plans were similar in the mean dose of the spinal cord and had no differences at statistically significant levels ($P<0.05$). With