

Dosimetric Comparative Analysis of Volumetric Modulated Arc Therapy and Intensity-Modulated Radiation Therapy in Cervical Cancer

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Abstract: *Objective:* To carry out dosimetric comparison between volumetric modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT) in cervical cancer. *Methods:* 50 postoperative cervical cancer patients were included in this study. The patients were admitted for treatment from January 2021 to January 2022. VMAT and IMRT plans were designed for each patient to analyze the dose distribution in the target area of the two treatment techniques. *Results:* Comparing the monitor unit for single treatment (638.21 ± 116.21 MU) and time of single treatment (143.21 ± 23.14 s) in the observation group and the monitor unit for single treatment (932.14 ± 74.11 MU) and time of single treatment (223.14 ± 17.26 s) in the control group, there was significant difference ($P < 0.05$); there was also significant difference ($P < 0.05$) between the normal tissue (bladder and rectum) of the observation group and that (bladder and rectum) of the control group. *Conclusion:* VMAT is more effective in cervical cancer, and it has a certain protective effect on normal tissues in patients and can reduce the radiation dose.

Keywords: Volumetric modulated arc therapy, Intensity-modulated radiation therapy; Radiotherapy for cervical cancer; Dose

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1. Introduction

Cervical cancer is a common malignant tumor of the female reproductive system. With the widespread application of cervical screening in recent years, cervical cancer can be detected and treated early. The peak period of cervical cancer incidence is bimodal; the first peak is between 40 and 50 years old, while the second peak is between 60 and 70 years old. Abnormal vaginal bleeding, abnormal vaginal discharge, and some late symptoms of compression are clinical manifestations of cervical cancer^[1], of which contact vaginal bleeding is the main symptom. This disease is also related to human papillomavirus (HPV) infection. There are high-risk types of HPV viruses, such as HPV 16 and 18, both of which are the main types that cause cervical cancer. In the treatment of cervical cancer, the three main methods are surgery, chemotherapy, and radiotherapy. The surgery that is commonly performed in patients with cervical cancer is known as extensive radical surgery. According to the patient's condition, fertility and the pelvic nerves can be preserved; especially in the early stages of cervical cancer, the ovaries are often preserved^[2]. Intensity-modulated radiation therapy (IMRT) is a radiotherapy technique. For patients with early-stage cervical cancer, postoperative adjuvant radiotherapy can effectively inhibit local recurrence. The prolonged treatment time of IMRT in the static field may easily lead to the increase in uncertainty factors in the

treatment process and affect the curative process. In addition, postoperative radiotherapy for cervical cancers may also lead to complications. Patients may develop certain reactions, such as gastrointestinal reactions, while other patients may have bowel adhesions as a result of radiotherapy. In severe cases, symptoms such as intestinal obstruction, radiation proctitis, hematochezia, tenesmus, *etc.*, will affect the health of patients [3]. On the basis of image-guided radiation therapy, volumetric modulated arc therapy (VMAT) is an advanced radiation therapy technique under the guarantee of three-dimensional dose verification by the reverse optimization treatment planning system and high-precision accelerator. VMAT uses a single arc or multiple arcs to irradiate the tumor at any angle. During the rotation of the ray beam, parameters such as dose rate, rack speed, and blade position can be dynamically adjusted. This technology has a larger irradiation range, more flexibility and precision, better dose focusing effect, and advantage in the irradiation of early-stage and complex tumors [4]. Compared with IMRT, rotating IMRT (VMAT) can effectively reduce the treatment time, while ensuring that the radiation dose to normal organs is low. Therefore, we analyzed the dosimetric difference between VMAT and IMRT in cervical cancer in this study to provide reference for clinical radiotherapy.

2. Materials and methods

2.1. Data

A total of 50 postoperative patients with cervical cancer were included in this study. The patients were admitted for treatment from January 2021 to January 2022. The average age of the patients was 56.17 ± 6.17 (40–70) years old. Inclusion criteria: (i) informed consent given; (ii) patients with complete clinical data. Exclusion criteria: (i) patients with other serious diseases; (ii) non-cooperative to postoperative treatment. The differences in baseline data between the two groups of patients were not statistically significant ($P > 0.05$).

2.2. Methods

Fixed body position, computed tomography (CT) simulation: All patients were required to empty their bladders 1 hour before the scan, drink 500 mL of water, and retain their urine; they were fixed with a thermoplastic body film, and CT was used to acquire plain and enhanced images; the range of the scan included the patient's perineum, pelvis, and middle and lower abdomen, with a slice thickness of 5 mm; the images were then transmitted to the Monaco planning system.

Radiotherapy plan design: (i) observation group (the starting angle of the gantry was 180° , and the arc was rotated 360° to and fro for irradiation); (ii) control group (5 fields were coplanarly irradiated, and the rack angles were 40° , 110° , 180° , 250° , and 320°).

2.3. Observation indicators

The doses to organs at risk and normal tissues were compared between the two groups.

2.4. Statistical analysis

SPSS 26.0 was used for statistical processing. $P < 0.05$ indicates significant difference in the data.

3. Results

3.1. Comparison of monitor unit and planned treatment time between the two groups

The monitor unit for single treatment (638.21 ± 116.21 MU) and single treatment time (143.21 ± 23.14 s) of the observation group were better than those of the control group (932.14 ± 74.11 MU; 223.14 ± 17.26 s), and the difference was statistically significant ($P < 0.05$), as shown in **Table 1**.

Table 1. Comparison of monitor unit and planned treatment time between the two groups

Group	Number of cases (n)	CI	HI	Monitor unit for single treatment (MU)	Single treatment time (s)
Observation group	25	0.81 ± 0.10	0.08 ± 0.01	638.21 ± 116.21	143.21 ± 23.14
Control group	25	0.71 ± 0.02	0.08 ± 0.02	932.14 ± 74.11	223.14 ± 17.26
<i>t</i>	–	2.0127	1.0123	16.4417	9.1728
<i>P</i>	–	0.0714	0.0918	0.0000	0.0000

Abbreviations: CI, conformity index; HI, homogeneity index.

3.2. Comparison of normal tissue dose between the two groups of patients

The normal tissue dose (bladder and rectum) of the observation group was significantly lower than that of the control group ($P < 0.05$), as shown in **Table 2**.

Table 2. Comparison of doses to normal tissues between two groups of patients

Group	Number of cases (n)	Bladder		Rectum	
		D _{10%} (cGy)	D _{max} (cGy)	D _{10%} (cGy)	D _{max} (cGy)
Observation group	25	3366.14 ± 228.14	4091.21 ± 317.26	4176.21 ± 556.14	4576.23 ± 536.11
Control group	25	4932.17 ± 187.21	5064.21 ± 23.14	4951.17 ± 109.14	4576.51 ± 531.24
<i>t</i>	–	21.1627	24.1128	23.2614	27.2914
<i>P</i>	–	0.0000	0.0000	0.0000	0.0000

4. Discussion

According to relevant research [4], cervical cancer mainly refers to canceration that occurs in female epithelium or glands. Among the different types of cervical cancer (cervical adenocarcinoma, squamous cell carcinoma, *etc.*), squamous cell carcinoma is the most common. The occurrence of cervical cancer is closely related to HPV infection, prolificacy, and long-term inflammatory stimulation. Commonly, there is no clinical manifestation in early cervical cancer, and the malignancy is often identified through inspection. Among the symptoms, bleeding after intercourse is the earliest symptom in the early stage of cervical cancer [5]. Cervical exfoliative cytology examination and HPV screening are generally performed in clinical practice to screen for cervical cancer, while pathological tissue biopsy and colposcopy are performed to confirm the diagnosis. If cervical cancer is not treated in time, there will be worsening of vaginal bleeding and irregular vaginal bleeding [6]. Once contact bleeding or postmenopausal bleeding occurs, it is necessary to seek medical attention, so that relevant examinations can be carried out in time to rule out the possibility of cervical lesions. In the treatment of cervical cancer, the treatment methods vary depending on the patient. In addition, different patients also have different prognoses. Clinically, surgical methods are usually used for cervical cancer, and they are generally suitable for patients with early cervical cancer. Surgery and postoperative adjuvant therapy are effective when the tumor has not invaded the parauterine tissue or metastasized. In such cases, the curative effect is high [7]. However, in most cases, when patients are diagnosed with cervical cancer, there is regional spread; hence, patients would have lost the best opportunity for surgery. For such patients, radiation therapy is the treatment of choice. Radiation therapy has been widely used in clinical practice. For early-stage cervical cancer, such as stage IA, stage IB, and stage IIA, hysterectomy is commonly performed, with adjuvant radiotherapy and chemotherapy after surgery. However, for advanced cervical cancer, such as stage IIB and above, radiotherapy can be performed.

With the advancements in treatment methods, the survival rate of cancer patients is increasing. Controlling the tumor while reducing the incidence and severity of side effects is one of the key issues that need to be considered in radiotherapy. The top priority in postoperative radiotherapy for patients with cervical cancer is to reduce the incidence and severity of bladder and bowel reactions. Radiotherapy is beneficial to postoperative patients with cervical cancer. In cervical cancer, radiation therapy mainly refers to three-dimensional conformal radiation therapy based on CT positioning. It can achieve high curative effect, high dose, high-precision irradiation on the tumor, and optimal protection of normal tissues and organs around the tumor. Three-dimensional conformal radiation therapy is constantly maturing and is considered to be a major breakthrough in radiation therapy for cancer. In traditional radiotherapy for cervical cancer, due to the influence of various factors, the tissue in the patient's pelvic cavity is easily exposed to high doses of radiation, which can cause severe acute and chronic side effects. There are different types of IMRT, including step-and-shoot IMRT, sliding window IMRT, volumetric IMRT, and tomotherapy, which can be divided into two types: (i) conventional tomotherapy and helical tomotherapy; and (ii) multi-leaf grating, which has many clinical applications. In clinical practice, the most appropriate and suitable treatment method should be used according to conditions to achieve the effect of treating tumors while protecting normal tissues and organs and reducing complications. The aforementioned IMRT types have been used clinically, rendering positive effects. Nowadays, with the extensive application of VMAT in clinical practice, certain effects have been achieved. During the rotation of the gantry, the volumetric intensity-modulated radiation produces beams continuously, and the shape and dose rate of the radiation field are also adjusted according to the requirements. Thus, reasonable dose distribution can be achieved.

Compared with the three-dimensional conformal technology, IMRT can improve the dose distribution in the target area, but the treatment time is significantly lengthened, resulting in a significant decrease in treatment accuracy. VMAT is optimized by dynamic multi-leaf grating through a rotating beam to achieve the required clinical dose; the intensity-modulated plan is then made to select the arcs of rotation, and the irradiation field, the beam, and the angle of incidence are optimized in the planning system. After optimization, the required dose distribution is achieved and transferred back to the computer manual planning system for treatment. VMAT is a novel technique that allows the precise control of multiple-parameter information during the rotation process of the accelerator frame, such as the position and dose of multi-level cell (MLC) and the angle of the frame at each control point. By adjusting the speed of the rotating gantry and the shape and weight of the field of view at the corresponding angle, it is possible to achieve ideal dose distribution. In general clinical cases, VMAT usually uses two arcs to achieve the ideal treatment plan. VMAT can reduce the number of machine jumps of the accelerator^[8]. In the present study, VMAT was used. VMAT shields the radiation when the radiation field is aimed at normal tissues, and although the gantry keeps rotating at a constant speed, it does not emit beams, thereby reducing the low-dose exposure of normal tissues on the radiation field path.

In the present study, the intensity modulation scheme of 5 fields was selected. In the actual treatment process, it takes a certain amount of time to switch the angle of the treatment field. If the field increases, the treatment time will also increase. In the VMAT plan, two irradiation arcs are selected. The end angle of the first treatment field becomes the starting angle of the next treatment field. There is no need to switch the angle of the treatment field, thereby preventing time wastage. According to statistics, for each patient treated, the VMAT plan can save about 8 minutes on average, which is of great significance to improving clinical efficacy.

Our research showed that there was significant difference ($P < 0.05$) in single treatment monitor unit and single treatment time between the observation group (638.21 ± 116.21 MU; 143.21 ± 23.14 s) and the control group (932.14 ± 74.11 MU; 223.14 ± 17.26 s); there was also significant difference ($P < 0.05$) in

normal tissue dose (bladder and rectum) between the observation group and the control group.

In conclusion, VMAT has a shorter treatment time and certain protective effect on normal tissues and can reduce the radiation dose in radiotherapy for cervical cancer; thus, it is worthy of promotion and application in clinical practice.

Disclosure statement

The authors declare no conflict of interest.

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