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Research Article

DOSIMETRIC COMPARISON OF 3D CONFORMAL RADIOTHERAPY (3D-CRT) AND VOLUMETRIC MODULATED ARC THERAPY (VMAT®) IN CERVIX CANCER: EXPERIENCE OF MOHAMMED VI CENTER FOR CANCERS TREATMENT CASABLANCA

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ABSTRACT

Backgraound: Radiochemotherapy supplemented with brachytherapy is a standard in the treatment of locally advanced cervix cancer. Conformal radiotherapy (3D-CRT) does not allow a good organ at risks sparing. Technological developments led to the emergence of Modulated Volumetric Arc Therapy (VMAT®), which showed a dosimetric value in pelvic irradiation compared to conformal radiotherapy (3D-CRT) for intestinal sparing and homogeneity of planning target volume coverage while decreasing treatment time.
The objective of the study is the dosimetric comparison of the conformal radiotherapy technique and VMAT® in cases of cervix cancer.
Methods: This is a comparative retrospective study of 17 cases treated in our center for cervix cancer by pelvic radiotherapy without lumbar-aortic radiation. The cases that received a 3D-CRT treatment were simulated in VMAT® and those who received a VMAT® irradiation were simulated in 3D-CRT. Data entry was done on Excel software and static analysis by Statistical Package for the Social Sciences (SPSS) software version 21.0.
Results: The mean coverage of the Planning target volume was lower with VMAT® ($p < 0.001$). This technique allowed better intestinal sparing ($p < 0.001$) , better bladder ($p < 0.001$) and rectal sparing ($p < 0.001$). Monitor units (MU) in VMAT® are much more important than in conformal radiotherapy (3D-CRT) ($p < 0.001$) which influences the treatment time; 4 minutes for VMAT® and 3 minutes for 3D-CRT.
Conclusion: The VMAT® is more interesting in matters of organ at risks sparing compared to the 3D-RCT, but with more monitor unites (UM) and a relatively longer processing time.

INTRODUCTION

Radio chemotherapy supplemented by brachytherapy is a standard in the treatment of locally advanced cervix cancer [1]. Before the arrival of intensity modulated radiotherapy (IMRT), the standard treatment of locally advanced cervix cancer was unmodulated conformal irradiation, which was the first step in optimizing radiotherapy for cervix cancer compared to the two-dimensional technique. Intensity modulated radiation therapy (IMRT) has demonstrated dosimetric superiority in digestive toxicity compared to three-dimensional conformal radiotherapy (3D-CRT) [2, 3].

Technological developments have led to the emergence of modulated volumetric arc therapy (VMAT®), which has shown its interest in pelvic irradiation compared to the static beam intensity modulated radiotherapy (IMRT) for intestinal sparing

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and coverage homogeneity of the Planning target volume (PTV) while decreasing the treatment time. [4, 5]

Cervix cancer radiotherapy involves a large target volume to treat (primary tumor, parameters, upper vagina and pelvic nodes), leading to partial irradiation of the rectum, bladder and Small intestine causing mainly digestive toxicity that can be further aggravated with the concomitant use of chemotherapy [6].

Modulated volumetric arc therapy employs arm rotation during treatment with segments and variable dose rate, thus avoiding separate beams [5].

The interest of the VMAT® technique is to maintain the same tumor control while decreasing intestinal toxicity and treatment time. its results must be evaluated and compared to those of obtained by the 3D conformal radiotherapy.

The objective of this work is to compare the dosimetric treatment plans simulated in 3D conformal radiotherapy and the VMAT® technique in patients treated for cervix cancer in our center to search for the advantages for our patients of the new technique recently installed.

PATIENTS AND METHODS

We performed a comparative retrospective study of 17 cases managed in our center for cervix cancer by pelvic radiotherapy without lumbar-aortic radiation. Clinical data were collected from patients' medical records. All the cases included in this study had received concomitant chemotherapy. The tumor stage was from stage IIB to IVA according to the classification of the International Federation of Gynecology and Obstetrics (FIGO).

The cases that received a 3D-CRT irradiation were simulated in VMAT® and those who received a VMAT® irradiation were simulated in 3D-CRT. The patients were supine, hands on their chests. The ankles and feet were immobilized by a footrest and a knee fix immobilization devices.

The dosimetric scanner was performed before and immediately after injection of contrast agent .

The 0.25 cm scan sections are made with a radiopaque vaginal marker. The volumes were delineated on the Eclips version 8.6 planning system (Varian Medical System). They were transferred to Monaco software version 5.11 (Elekta).

The same delineated structures were used for planning both techniques.

The target volumes were Tumoral clinical target volume T (CTV T) = Tumoral gross target volume (GTV T) + uterus + appendix + parameters + safety margins at the vagina, Nodal clinical target volume (CTV N) = Nodal gross target volume (GTV N) + iliac, obturator and pre-sacral lymph nodes), and planning target volume (PTV) = clinical target volume CTV (=CTV T+CTV N) + 1cm.

The delineated risk organs were the rectum, the bladder, the intestine (delineating the peritoneal cavity on the sections included in the irradiation beams) and the femoral heads. All patients received a dose of 46Gy in 2Gy per photon session of 18MV for conformal radiotherapy (3D-RCT) and 6MV for modulated volumetric arc therapy (VMAT®).

The algorithm used for 3D irradiation is Collapsed-Cone and Monte Carlo for irradiation with VMAT®.

The goal of the dosimetry was a good coverage of the planning target volume (PTV) in the first place, and a good intestinal, bladder, rectal and femoral heads spare.

For 3D, we used a ballistic of 4 orthogonal beams with angles of: 0 °, 180 °, 270 ° and 90 °. The one-point prescription is made according to International Commission on Radiation Units and Measurements 62 (ICRU 62) [7].

Beam modifications were used to avoid overdose points outside the predicted target volume, with a weighting of 60% for the anterior / posterior fields and 40% for the lateral ones.

For modulated volumetric arc radiotherapy, a beam was generated with two 360 ° arcs: the first in the counter clockwise direction and the second in the clockwise direction, without collimator rotation. Dose constraints were applied for small intestine, bladder, rectum and femoral heads.

To compare the two techniques, normalization was performed so that 95% of the PTV received a dose of 100% of the prescribed dose.

For the comparison, we have noted the D_{max} which corresponds to the maximum dose received by a given volume, the D_x which corresponds to the dose received by the volume x% of the treated volume and V_x the volume in Cm^3 which corresponds to the volume receiving x% of the dose.

Dmax, Dmean, D_{98}, D_{95}, D_5 and D_2 were collected for the planning target volume.

For organs at risk, we have identified the V_{30Gy}, V_{46Gy} and $V_{49,22Gy}$ for the bladder, which corresponds to the 107% of the prescribed dose (46Gy).

For the rectum we identified the V_{20Gy} in addition to the values recorded for the bladder. For the small intestine we used the V_{30Gy}, V_{40Gy}, V_{45Gy} and $V_{49,22Gy}$.

Data entry was done on Excel software and static analysis by SPSS software version 21.0.

RESULTS

A total of 17 cases managed in our center with concomitant chemotherapy containing cisplatin 40 mg/m^2 weekly in 16 patients and carboplatin-based AUC 5 in a single patient. The tumors were squamous cell carcinomas, classified according to International Federation of Gynecology and Obstetrics (FIGO), nine IIB, five IIIA, two IIIB and one IVA.

Target volumes of the two compared techniques were not identical, showed a difference in the homogeneity index values ($p < 0.001$) and the conformity index ($p < 0.001$), the different results are reported in the table 1.

Table 1 Comparison of doses received by the target volume and organs at risk with VMAT® techniques and the 3D technique in cervix cancer.

	3D	VMAT®	*p*
Target volume			
Homogenety index	0,075 (0,003)	0,055 (0,002)	<0.001
Conformity index	0,98 (0,004)	0,893 (0,013)	<0.001
Dose mean	48,03 (0,17)	46,04 (0,12)	<0.001
Dose maximal	50,35 (0,22)	49,49 (0,12)	0,004

Small Intestine (cm^3)			
V_{30Gy}	439,4 (74,80)	344,49 (50,50)	0,024
V_{40Gy}	247,35 (43,04)	159,36 (30,18)	<0.001
V_{45Gy}	188,03 (38,32)	68,09 (18,6)	<0.001
$V_{49.22Gy}$	33,28 (16,73)	0 (0,00)	0,064
Bladder (%)			
V_{30Gy}	98,35 (2,29)	81,0 (5,26)	<0.001
V_{46Gy}	83,94 (11,77)	33,41 (8,65)	<0.001
$V_{49.22Gy}$	4,71 (9,18)	0 (0,00)	0,05
Rectum (%)			
V_{30Gy}	96,96 (1,42)	91,47 (1,91)	0,003
V_{46Gy}	78,9 (2,90)	42,4 (3,29)	<0.001
$V_{49.22Gy}$	12,66 (5,05)	0 (0,00)	0,023
Monitor Unit			
UM	241,18 (11,07)	814,82 (77,58)	<0.001

PTV

The index of homogeneity corresponds to ($D_{5\%}$ -$D_{95\%}$) / D_{mean}, and must tend towards 0. The index of conformity corresponds to $V_{99\%}$ / V_{total}, and must tend towards 1.

The two techniques were not identical for the homogeneity index and Planning target volume coverage values (p <0.001). The homogeneity index was less satisfactory for the conformal radiotherapy (3D-CRT) technique than for the VMAT® technique, whereas the conformity index is better for the conformal technique. The mean dose was higher for the 3D technique compared to the VMAT® technique (p <0.001), the maximum dose was greater than 107% of the dose prescribed for the first technique, whereas less than or equal to 107% for the second.

Small Intestine

Intestinal savings were better at all dose levels (V_{30Gy}, V_{40Gy}, V_{45Gy} and $V_{49.22Gy}$) for the VMAT® technique (Tab1). The 30Gy dose covered 439.4Cm^3 in the conformational technique and 344.49Cm^3 by VMAT® and the 45Gy dose covered 188.03Cm^3 in the first technique but 68.09Cm^3 for the second technique. The difference is very significant, the VMAT® spares more the small intestine compared to the conformal technique (p <0.001).

Rectum

In the rectum, there is a difference between the two techniques, the rectal V_{46Gy} was greater with conformal radiotherapy (78.9%) than with VMAT® (42.4) (p <0.001). This difference was observed on V_{30Gy} and $V_{49,22Gy}$ respectively with p = 0.003 and p <0.02 (Table 1).

Bladder

In the bladder The V_{46Gy} was significantly greater with the conformal technique (83.97%) than the VMAT® technique (33.41%), (p <0.001). The results were similar for V_{30Gy} and $V_{49,22Gy}$ (respectively p <0.001 and (p = 0.051).

Note: For the $V_{49,22Gy}$, the standard deviation is twice high as than the average value, this is explained by the very large values of one of the 17 records selected for this study.

MU

The number of monitor units (MU) is greater with VMAT® (814.82) compared to treatment with conformal radiotherapy (3D-CRT) (241.18). It directly influences the treatment time under the machine which varies between 3 to 4 minutes for VMAT® treatment and 2 to 3 minutes for 3D.

DISCUSSION

Intensity modulated radiotherapy (IMRT) is one of the potentially efficient optimization methods to better protect the digestive tract during cervix cancer irradiation by analogy with the results obtained for prostate cancer [1,2,3].

In fact, the acute and chronic toxicities of pelvic radiotherapy in cervix cancers are essentially digestive, manifesting themselves in grade 2 or even 3 effects [6, 8].

Modulated volumetric arc therapy showed superiority in dosimetry compared with non-modulated conformal radiotherapy but also compared to static beam IMRT.

For our study, the VMAT® technique allows a better homogeneity of the target volume compared to the 3D conformal technique, this is consistent VMAT®with the study of Cozzi *et al*. [8]. However, for the conformity, the VMAT® did not show superiority.

The intestinal savings, which was the main objective for organs at risk, is better in all dose levels with the VMAT® technique resulting in a lower clinical digestive toxicity. Acute toxicity of grade 2 or greater has been shown to be demonstrated with intestinal volume receiving 40 and 50Gy [9, 10].

In our study the volume of the small intestine receiving 45gy was significantly reduced with the VMAT® technique (68.09) compared to the 3D technique (188.03), this is consistent with the results of the first dosimetric study of Roeske *et al*. [9] where the volume of the small intestine receiving 45gy was decreased by 50% with IMRT.

We obtained a significant gain for the bladder and the rectum since the V_{46gy} of the bladder is smaller with the VMAT® technique as well as the V_{46gy} of the rectum.

In the study by Roeske *et al*. ,the volume of rectum and bladder receiving the prescribed dose was only 23% [9], so the rate of cystitis was decreased by 50% in the results reported by the team of Mundt *et al*. [5, 11, 12].

The interest of the VMAT® is to obtain results at least comparable to the IMRT with static beams, with a reduction in processing time. On the one hand, by the decrease in the number of monitor units, and on the other hand, because the pelvic IMRT requires the use of splitted beams while the VMAT® treats all the height of the target volume at the same time [4].

In our study, the number of UM is greater with the VMAT® compared to the 3D conformal technique which leads to a comparable treatment time between the two techniques (3 to 4 min for the VMAT® and 2 to 3 min for the 3D-CRT).

CONCLUSION

The VMAT® technique is therefore very interesting for the management of cervix cancers, in particular by ensuring better intestinal savings with good homogeneity and coverage of the target volume. In our department, the VMAT® technique is now used in routine practice with preparation of treatment sessions with Image-guided radiation therapy(IGRT) on-board imaging and systematic collection of toxicity according to the Common Terminology Criteria for Adverse Events v3(CTCAE v3) scale and monitoring of local control.

Our perspective is to extend the technique to patients with cervix cancer and requiring lumbar-aortic irradiation and also to measure the impact of VMAT®

Declaration of Interests

The authors declare that they have no conflict of interest

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