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A Dosimetric Evaluation and Comparison of Point A and Volume Based HDR Intracavitary Brachytherapy

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Abstract **Original Research Article**

This study aims to compare two different plans, point A based 3-dimensional intracavitary brachytherapy (3D-ICBT) plan and volume-based 3D-ICBT plan in cervical carcinoma with the help of dosimetric parameters.

Methods: 30 patients with large tumor volume who received CT image-based point A treatment planning method were replanned to volume-based planning using a treatment planning system for this study. The patient was given a 7 Gy per fraction total 21Gy in 3 fractions is considered for this study. The dose to organ at risk (OARs), bladder, rectum and intermediate clinical target volume (IR-CTV) was compared between both point A based plan and volume based (volume optimization) treatment plan.

Results: The total mean doses of IR-CTV D90 and D80 is 15.64 Gy and 19.03 Gy respectively for volume optimization plan and 12.82 Gy and 16.14 Gy for point A based plan. The doses of intermediate CTV for volume optimization show significantly higher than point A based plan ($p<0.001$). And bladder dose for 0.2cc and 2cc is 18.64 Gy and 15.72 Gy respectively for volume optimization and 25.12 Gy and 19.87 Gy respectively for point A based plan. Similarly, 0.2cc and 2cc rectum dose for volume optimization is 17.82 Gy, 14.63 Gy respectively and 21.05 Gy and 16.48 Gy for point A based plan. So, the OARs doses show significantly lower than point A based plan in large volume lesion($p<0.001$).

Conclusion: This study demonstrates that volume optimization-based plan can reduce organ at risk (OAR) doses and also get better tumor coverage than point A based plan in large volume lesion.

Keywords: Intracavitary Brachytherapy, Volume-Optimization, Point A, Organ at Risk, Intermediate CTV.

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1. INTRODUCTION

Cervical cancer is the fourth most common cancer in women worldwide. In 2022, an estimated 66,0000 women were diagnosed with cervical cancer worldwide, and 350,000 women died from the disease [1]. The most recommended treatment for cervical cancer patients in locally advanced stage is managing it by its definitive irradiation, and a well-considered course of treatment is external beam radiation therapy followed by HDR intracavitary brachytherapy. The overall dose that the gross tumor is receiving plays a vital role in the treatment's success. Brachytherapy is basically a treatment that helps to deliver a high dose to the target and spare the organs to a great extent that are at risk, like the rectum and bladder, within a short span of time.

Conventionally, the planning of intracavitary brachytherapy (ICBT) was orthogonal Xray images with point A based, and in order to determine the dose to the critical organs that are at risk, bladder and rectal points were delegated. These representative points are defined in ICRU 38[2,3,4]. Nowadays, advanced imaging systems like CT and MRI allow 3D delineation of the OARs and CTV. A working group, Groupe European de Curietherapie (GEC) and European society for Radiotherapy and Oncology (ESTRO) [5,6] has presented guidance for delineation of CTV and dose reporting for 3D image (CT or MRI) based brachytherapy for cervix [5]. The treatment plan can be created within a short time with the help of a computerized planning system while performing dose calculations that are accurate and error- free and also reduce the dose to OARs through optimization. The ICBT planning with

the CT based point A method in terms of IR-CTV and doses for OARs is followed by our institution. The IR-CTV and other dosimetric parameters are considered for this study. The other studies show that for a point A -based plan, the OAR, i.e., bladder and rectum dose is high. Therefore, increasing the chances of bladder and rectum toxicity.3D ICBT with volume optimization planning can reduce OARs doses through optimization. This study, compares the 3D ICBT with point A-based plan and volume optimization plan to determine which of these plans gets better coverage and minimum OARs dose in large volume lesions.

2. METERIALS AND METHODS

This study is a retrospective observational study.30 cervix cases treated during 2019-2024 and a dose prescribed 7Gy in 3 fractions with a large volume of >30 cc was selected for this study.

2.1. PROCEDURE OF INSERTION

The procedure of insertion was performed in the OT room with the patient positioned in the lithotomy position. Fletcher suit applicator with tandem and ovoids of selected angle, length and geometry are used to insert the patient body for ICBT. Vaginal packing was done for fixing the applicator in position.

2.2. COMPUTED TOMOGRAPHY SIMULATION

Patients after the insertion are positioned on the CT and simulated in a manner of head- first supine.3D imaging of treatment volume was done by acquiring axial CT images with a thickness of 3mm using Siemens SOMATOM. Once the scanning was done, the obtained CT images were reconstructed and sent to the treatment planning system (TPS) for delineating the target volume along with the OAR within the CT images.

2.3 IMAGE REGISTRATION AND CONTOURING

The acquired CT slices are transformed via DICOM to Varian Eclipse 15.6 TPS and were imported into the system. The radiation oncologists contoured the CTV and OARs on each axial CT scan for the particular brachytherapy fraction based on the American brachytherapy system (ABS) [7]. The CTV was drawn on the basis of guidelines presented by GEC-ESTRO [5,6] IR-CTV was considered for this study.

2.4. BRACHYTHERAPY TREATMENT PLANNING

Treatment planning was done using the BrachyVision treatment planning system of Gamma med plus HDR brachytherapy supplied by Varian. For all cases, ICRU-38[2] and ABS guidelines [7] were followed for placing point A. Using the two different prescription methods point A plans and volume-based plans were developed for each patient. For the purpose of this study 7Gy was prescribed to point A for the-point A based plan and to the CTV for the volume-based plan for each fraction. The total prescribed dose for this study is 21 Gy in 3 fractions. The IR-CTV doses $D_{90\ and}$ D_{80} were noted separately for both plans in each fraction, and 0.2cc and 2cc dose for bladder and rectum dose (D0.2cc and D2cc) were also noted for both plans.

2.5 PLAN EVALUATION

The quantitative evaluation and analysis of the plans generated with both point A -based plan and volume optimization plan were performed by means of standard dose volume histogram or DVH analysis.

2.6. STATISTICAL ANALYSIS

Statistical analysis was carried out using Jamovi Software. Dose levels were described by mean and standard deviation. The Shapiro-wilk test was used to check the normality of parameters. Paired t test is used for normally distributed parameters and Wilcoxon test is used for non-normal parameters. The significance level was determined as $p<0.05$ for both tests.

3. RESULTS

In all 30 cases IR-CTV doses and OARs doses were compared. Table 1 shows the comparison of IR-CTV D_{90} and D_{80} doses for both plans. The total mean doses for IR-CTV D_{90} and D_{80} for the volume-based plan are higher than point A based plan. The total mean doses for IR-CTV D_{90} and D_{80} for the volume optimization plan is 15.64Gy and 19.03Gy respectively and while, for the point A based plan, they are 12.82 Gy and 16.14Gy respectively.

The comparison of the D0.2cc and D2cc bladder for both plans is shown in table 2. The total mean for D0.2cc and D2cc bladder for volume-based plan is18.64Gy,15.72Gy respectively and 25.12Gy,19.87Gy for point A based plan. This indicates that D0.2cc and D2cc for bladder is lower than point A based plan.

Likewise, the D0.2cc and D2cc rectum for both plans are displayed in table 3. Comparing the rectum doses for two plans in table 3, we observed that total mean D0.2cc and D2cc for volume-based plan is lower than point A based plan. For both plans the total mean D0.2cc and D2cc for rectum are 17.82Gy,14.63Gy and 21.05Gy,16.48Gy respectively.

As per statistics given in Table 3, the comparison of total doses for 3 fractions between the point A based plan and the volume-based plan is on the basis of Mean±SD along with p values. The total mean doses of IR- CTV D_{90} and D_{80} were significantly higher in volume-based plan than point A based plan (p-value <0.001). The total mean D0.2cc and D2cc bladder and D0.2cc and D2cc rectum for volume-based plan are significantly lower than point A based plan.

The DVH graphs of the OARs and the IR-CTV compared for a case is shown in figure 1, figure 2 & figure 3. The figure 1 shows DVH for IR- CTV doses for one fraction of one case. Similarly in figure 2&3 shows DVH for bladder and rectum

Table 1. The CTV D_{90} and D_{80} for both plans

No. of fractions	Point A based		Volume-based	
	IR- CTV		IR- CTV	
	D_{90}	D_{80}	D_{90}	D_{80}
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
1st fraction	4.94±1.17	5.89±1.05	5.57±1.01	6.17±0.92
2nd fraction	4.61±1.47	5.70±1.51	5.34±1.32	6.17±1.18
3rd fraction	4.71±1.42	5.89±1.56	5.24±1.29	6.32±1.25
Total dose	12.82±4.21	16.14±4.35	15.64±4.98	19.03±4.67

Table 2. D0.2cc and D2cc bladder for both plans

No. of fractions	Point A based		Volume-based	
	Bladder		Bladder	
	D 0.2cc	D 2cc	D 0.2cc	D 2cc
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
1st fraction	8.21±2.34	6.81±1.12	7.02±1.89	5.96±0.85
2nd fraction	8.58±2.11	6.87±1.34	6.81±1.55	5.57±1.02
3rd fraction	8.28±2.34	6.55±1.41	6.75±1.68	5.37±1.05
Total dose	25.12±5.83	19.87±3.95	18.64±3.72	15.72±2.89

Table 3. D0.2cc and D2cc rectum for both plans

No. of fractions	Point A based		Volume -based	
	Rectum		Rectum	
	D 0.2cc	D 2cc	D 0.2cc	D 2cc
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
1st fraction	7.58±2.01	6.32±1.07	6.16±1.45	5.29±0.78
2nd fraction	7.25±1.89	5.89±1.14	6.12±1.33	4.96±0.79
3rd fraction	7.02±1.92	5.74±1.18	5.91±1.37	4.93±0.85
Total dose	21.05±4.12	16.48±2.76	17.82±3.45	14.63±2.31

Table 4. Total doses of IR-CTV and OARs in 3 fractions for both plans with p values.

Dosimetric parameters	TOTAL DOSES OF 3 FRACTIONS		p-value
	Point A based	volume based	
	Mean±SD	Mean±SD	
IR-CTV-D_{90}	12.82±4.21	15.64±4.98	P <0.001
IR-CTV-D_{80}	16.14±4.35	19.03±4.67	P <0.001
Bladder-0.2cc	25.12±5.83	18.64±3.72	P <0.001
Bladder- 2cc	19.87±3.95	15.72±2.89	P <0.001
Rectum- 0.2cc	21.05±4.12	17.82±3.45	P <0.001
Rectum- 2cc	16.48±2.76	14.63±2.31	P <0.001

Figure 1 comparison of DVH for IR-CTV for both plans. The square shape indicates the point A based plan and triangle shape indicates volume -based plan for one case

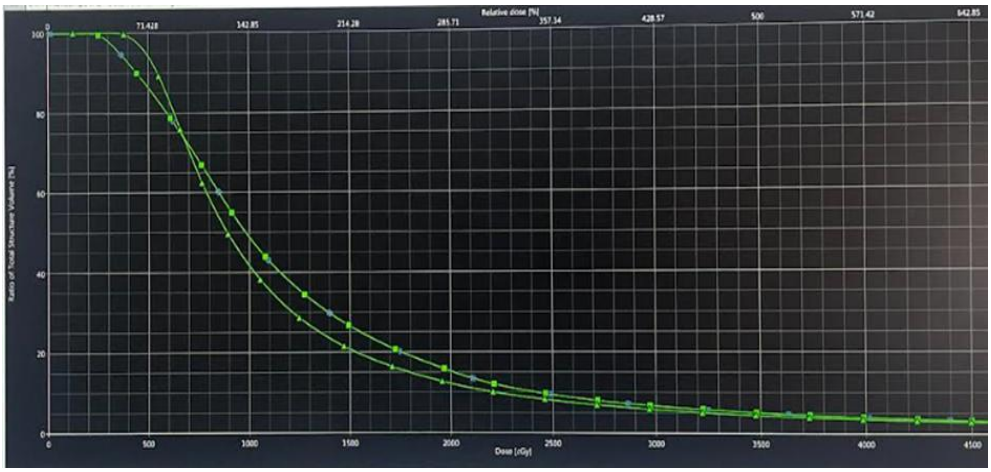


Figure 2 comparison of DVH for bladder for both plans. The square shape indicates the point A based plan and triangle shape indicates volume- based plan for one case

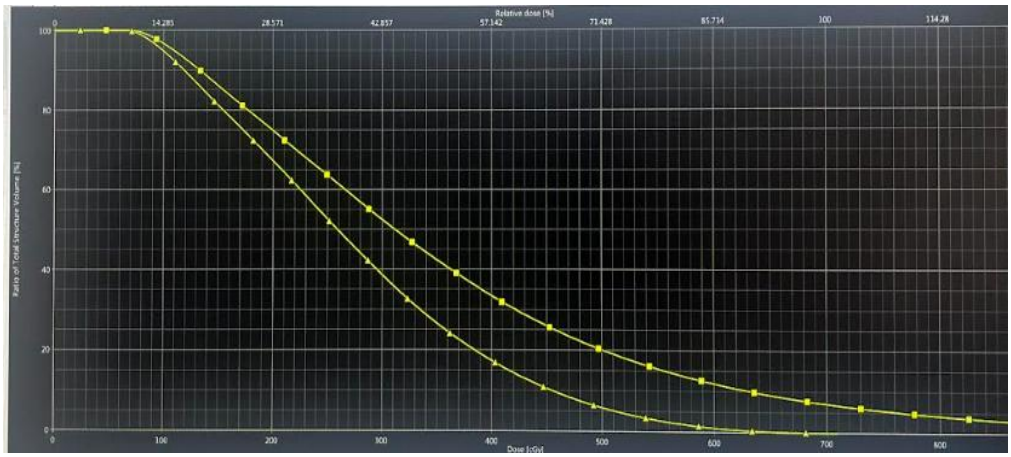
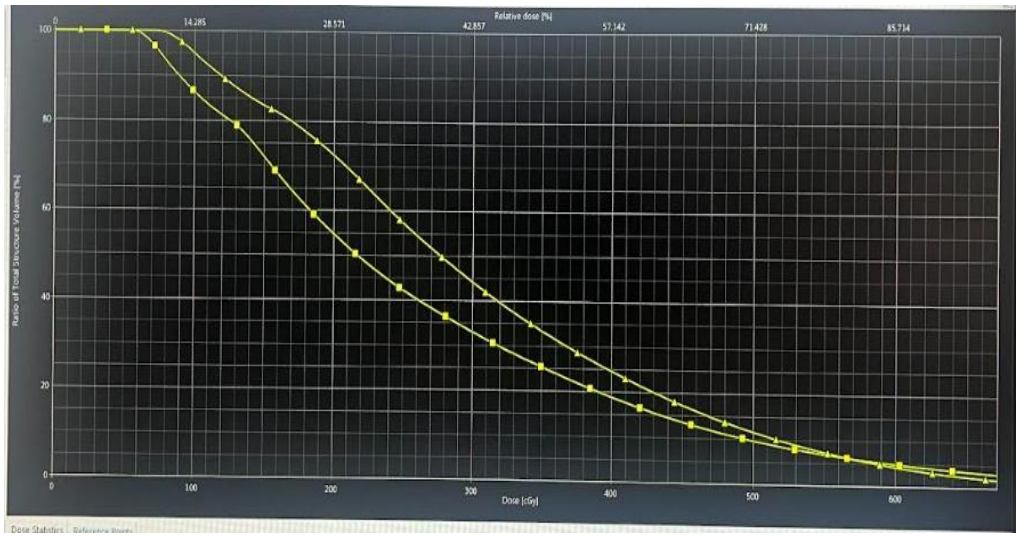


Figure 3 comparison of DVH for rectum for both plans. The square shape indicates the point A based plan and triangle shape indicates volume- based plan for one case



4. DISCUSSION

As we previously covered, cervical cancer is thought to be one of the main causes of death for women globally. The advanced techniques can help lower this mortality rate by reducing the toxicity in the OARs and improving the quality of treatment, which will increase the chances of survival.

In this study we focused to compare two different plans dosimetrically in terms of IR-CTV and OAR. Plans were originally generated using CT based point A prescription plan were replanned to the volume-based plan with CTV normalization and optimization with an intent to lower the OARs doses and to increase volume coverage

The study by Vipul Mehta et al., 2022. they compared 2D And 3D radiography-based brachytherapy. They observed 3D-ICBT Treatment planning is better to overcome insufficient tumor coverage and high dose to tumor [8]. In current study we compare 3D-point A based plan and volume-based plan in terms of IR-CTV and OARs.

Another study by Elif Eda Ozer et al., 2021, they compared two different plans normalized to point A and HR-CTV in terms of target volume and doses of OAR for small lesion [9]. This study evaluates the plan normalized to HR CTV can reduce over dose in the target tissue and avoid unnecessary OAR irradiation compared to the plan normalized to point A. Their study shows that, for small volume lesion the target tissue gets overdosed when normalize to point A. But it can be lower when normalized to HR-CTV. We take into account large volume lesion or IR-CTV, in our investigation. For point A based plans, there is no overdose in IR-CTV and in volume optimization plan IR-CTV coverage is improved.

According to the findings of our study, plan created with volume-based optimization have better coverage and low OARs doses. The results achieved from this study indicates that the volume-based plan can be considered efficient plan as it provides better sparing of the OAR while maintaining the adequate coverage in tumor volume IR-CTV. The limitation of our study is that, we only consider the dosimetric comparison of two planning systems. In order to convey the study's overall radiobiological significance, we may have used doses in biologically equivalent doses or EQD2.

5. CONCLUSION

The plan generated with the 3D-ICBT volume-based technique can be adopted for the treatment of intracavitary brachytherapy for cervical cancer to a great extent as it can be lower the dose to OARs without lowering IR-CTV coverage for large volume lesion. So limiting the chances of bladder and rectum toxicity and therefore we can consider 3D-ICBT volume- based plan is a more efficient technique of planning than a point A based plan.

FINANCIAL DISCLOSURE

None for all authors

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was approved by the institutional review board and the ethics committee, IEC Ref No:111/24 date of approval 29.10.2024

DECLARATION OF THE COMPETING INTEREST

"The author declares no conflict of interest"

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