

Dosimetric plan evaluation in interstitial brachytherapy for female genital organ malignancies: a prospective observational study.

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Abstract

Background:

Interstitial brachytherapy (ISBT) is used for selected gynecological malignancies when conventional intracavitary brachytherapy may provide inadequate target coverage because of bulky, irregular, or anatomically unfavorable disease. This study evaluated the dosimetric quality of ISBT plans with emphasis on target coverage and sparing of organs at risk.

Aim:

To evaluate the dosimetric parameters of interstitial brachytherapy in women with female genital organ malignancies treated at a tertiary care center.

Materials and Methods:

This prospective observational study was conducted at the Department of Radiation Oncology, Indira Gandhi Institute of Medical Sciences, Patna, from January 2024 to December 2025. Thirty women with cervical, vaginal, or vulvar malignancies requiring interstitial brachytherapy were included. Three-dimensional computed tomography-based treatment planning was performed. The high-risk clinical target volume (HR-CTV) and organs at risk, including the bladder, rectum, sigmoid colon, and bowel, were contoured. Dosimetric parameters, including HR-CTV D90, D98, D50, V100, V150, V200, organ-at-risk D2cc, conformity index, homogeneity index, dose non-uniformity ratio, and cumulative equivalent dose in 2-Gy fractions (EQD2), were evaluated.

Results:

The mean age was 54.7 ± 10.8 years. Cervical carcinoma was the most common malignancy (73.3%). Mean HR-CTV D90 was 7.1 ± 0.5 Gy, corresponding to $103.6 \pm 6.9\%$ of the prescribed dose, and mean V100 was $94.8 \pm 3.7\%$. Twenty-seven patients (90.0%) achieved HR-CTV D90 $\geq 100\%$. Mean cumulative bladder, rectal, and sigmoid D2cc EQD2 values were 78.4 ± 8.6 , 67.2 ± 6.9 , and 64.8 ± 7.1 Gy, respectively. No grade ≥ 3 acute gastrointestinal or genitourinary toxicity was observed.

Conclusion:

Three-dimensional image-guided ISBT provided satisfactory target coverage with acceptable organ-at-risk doses.

Recommendation:

Larger prospective studies with longer follow-up are recommended to evaluate long-term toxicity and oncological outcomes.

Keywords: Interstitial brachytherapy; gynecological cancer; dosimetry; high-risk clinical target volume.

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1. Introduction

Gynecological malignancies remain an important cause of cancer morbidity and mortality among women worldwide. Cervical cancer represents one of the most common malignancies affecting women in low- and middle-income countries, while vaginal and vulvar malignancies account for smaller but clinically important proportions of gynecological cancers.¹⁻⁶ Radiotherapy, including external beam radiotherapy (EBRT) and brachytherapy, constitutes an essential component of definitive treatment for locally advanced cervical cancer and selected vaginal and vulvar malignancies.⁷

Brachytherapy permits delivery of a high radiation dose directly to the tumor while producing a rapid dose fall-off in surrounding normal tissues. Conventional intracavitary brachytherapy is highly effective when the tumor geometry permits appropriate placement of the applicator. However, intracavitary treatment may become suboptimal in patients with bulky residual disease, parametrial extension, irregular vaginal involvement, distorted anatomy, or lesions that are not adequately encompassed by conventional applicators.^{1,2,8}

Interstitial brachytherapy involves the placement of radioactive-source-containing needles or catheters directly into or around the tumor-bearing tissues. This technique allows greater flexibility in shaping the high-dose region around irregular target volumes. The development of three-dimensional image-guided brachytherapy has further improved treatment planning by permitting delineation of the high-risk clinical target volume (HR-CTV) and OARs using computed tomography (CT) or magnetic resonance imaging (MRI).⁹⁻¹¹

The GEC-ESTRO recommendations established volumetric dose parameters such as D90 and D98 for target assessment and D2cc for evaluation of the most exposed 2 cm³ of OARs.^{12,13} The American Brachytherapy Society (ABS) also recommends volumetric assessment of target coverage and OAR doses during image-guided brachytherapy.^{1,2} For cervical cancer, commonly accepted cumulative EQD2 constraints include approximately 90 Gy for bladder D2cc and 70–75 Gy for rectum and sigmoid D2cc.^{1,2,14}

The use of interstitial brachytherapy can improve target coverage while reducing unnecessary irradiation of adjacent normal tissues, particularly in anatomically unfavorable disease. Previous dosimetric investigations have demonstrated that interstitial techniques may provide improved OAR sparing compared with intracavitary approaches in selected patients.^{8,15}

However, dosimetric evaluation remains highly dependent on patient anatomy, implant geometry, target volume,

needle placement, treatment planning technique, and optimization strategy. Therefore, systematic assessment of treatment plans is important for evaluating the quality and safety of interstitial brachytherapy in routine clinical practice.

Therefore, this prospective observational study was conducted to evaluate the dosimetric parameters of interstitial brachytherapy in women with female genital organ malignancies treated at Indira Gandhi Institute of Medical Sciences (IGIMS), Patna, with particular emphasis on HR-CTV coverage and doses delivered to the bladder, rectum, sigmoid colon, and bowel.

2. Materials and Methods

2.1 Study Design and Setting

This was a **prospective observational study** conducted in the Department of Radiation Oncology, Indira Gandhi Institute of Medical Sciences (IGIMS), Patna, Bihar, India. The study was conducted from **January 2024 to December 2025**. During this period, a total of **30 patients** meeting the predefined eligibility criteria were prospectively enrolled.

2.2 Study Population

The study population comprised women aged ≥ 18 years with histologically confirmed gynecological malignancies who were considered suitable for interstitial brachytherapy by the treating radiation oncology team.

Patients with cervical, vaginal, or vulvar malignancies were considered for interstitial implantation when clinically indicated because of residual disease, bulky or irregular tumor geometry, inadequate target coverage with conventional intracavitary techniques, or unfavorable anatomical configuration.

2.3 Inclusion Criteria

Patients were eligible for inclusion if they fulfilled all of the following criteria:

1. Female patients aged ≥ 18 years.
2. Histologically confirmed malignancy involving the cervix, vagina, or vulva.
3. Clinical indication for interstitial brachytherapy.
4. Completion of or ongoing definitive external beam radiotherapy (EBRT) as part of the treatment course.
5. Eastern Cooperative Oncology Group (ECOG) performance status of 0–2.
6. Adequate imaging available for treatment planning and target delineation.
7. Ability to undergo anesthesia and interstitial implantation.

8. Provision of written informed consent for participation.

2.4 Exclusion Criteria

Patients were excluded if they met any of the following criteria:

1. Previous pelvic radiotherapy.
2. Distant metastatic disease requiring palliative treatment.
3. Inability to undergo brachytherapy implantation.
4. Severe medical comorbidity precluding the procedure.
5. Incomplete treatment-planning datasets.
6. Inadequate imaging for target or organ-at-risk (OAR) delineation.

Patients who declined participation were not enrolled in the study and were therefore not considered part of the enrolled study population.

2.5 Measures to Address Potential Bias

Potential selection bias was minimized by applying predefined eligibility criteria consistently to patients considered for interstitial brachytherapy during the study period. Measurement bias was minimized by using a standardized three-dimensional computed tomography (CT)-based treatment-planning approach and by evaluating predefined target-volume and OAR dosimetric parameters across treatment plans. Data were recorded prospectively in a structured database to minimize errors in data recording and reporting.

2.6 Brachytherapy Technique

Before implantation, patients underwent clinical examination and imaging assessment. The decision to perform interstitial brachytherapy was based on tumor extent, anatomical configuration, residual disease, and the anticipated ability to achieve adequate target coverage.

Interstitial needles or catheters were inserted under appropriate anesthesia using image-guided techniques. Ultrasound guidance was used when appropriate to facilitate accurate implant placement and minimize the risk of injury to adjacent organs.

Following implantation, three-dimensional CT imaging was performed for treatment planning. The implanted needles were reconstructed on the treatment-planning system, and the treatment plan was generated using a high-dose-rate (HDR) iridium-192 source. The use of three-dimensional CT-based planning is consistent with established recommendations for interstitial gynecological brachytherapy.^{1, 2, 16}

2.7 Target Volume Delineation

The high-risk clinical target volume (HR-CTV) was delineated based on clinical examination, pretreatment imaging, treatment response, and post-implant imaging findings.

The following target-volume dosimetric parameters were evaluated:

1. HR-CTV D98
2. HR-CTV D90
3. HR-CTV D50
4. HR-CTV V100
5. HR-CTV V150
6. HR-CTV V200

D90 represented the dose received by 90% of the HR-CTV, whereas V100 represented the percentage of the HR-CTV receiving at least 100% of the prescribed dose.

Volumetric assessment of target coverage was performed in accordance with the principles of GEC-ESTRO recommendations.^{9–13}

2.8 Organs at Risk

The following organs at risk (OARs) were contoured:

1. Urinary bladder
2. Rectum
3. Sigmoid colon
4. Small bowel, when located near the treatment volume
5. The principal OAR dosimetric parameters evaluated were:
6. Bladder D0.1cc
7. Bladder D2cc
8. Rectum D0.1cc
9. Rectum D2cc
10. Sigmoid D0.1cc
11. Sigmoid D2cc
12. Bowel D2cc, where applicable

D2cc was defined as the dose received by the most irradiated 2 cm³ of the respective organ.^{12,13}

2.9 Treatment Prescription

Patients received HDR interstitial brachytherapy, predominantly at **7 Gy per fraction for three fractions**, according to individual clinical circumstances and institutional practice.

The brachytherapy dose was combined with the EBRT dose to calculate the cumulative equivalent dose in 2-Gy fractions (EQD2). An α/β ratio of 10 Gy was used for tumor tissue, whereas an α/β ratio of 3 Gy was used for late-responding normal tissues.

EQD2 was calculated using the following formula:

$$EQD2 = D \times [(d + \alpha/\beta)/(2 + \alpha/\beta)]$$

where **D** represents the total dose, **d** represents the dose per fraction, and α/β represents the tissue-specific α/β ratio.

This approach was used to evaluate the combined biological effect of EBRT and HDR brachytherapy.^{1,2,14}

2.10 Dosimetric Plan Evaluation

Treatment plans were evaluated using dose-volume histograms (DVHs). The principal criteria used for treatment-plan evaluation included:

1. Adequate HR-CTV coverage.
2. HR-CTV D90 approaching or exceeding the prescribed dose.
3. Minimization of radiation doses to the bladder, rectum, sigmoid colon, and bowel.
4. Avoidance of excessive high-dose volumes.
5. Appropriate dose conformity around the target.
6. Acceptable treatment geometry.

Cumulative EQD2 values were also assessed in relation to commonly used OAR dose constraints, including approximately 90 Gy for bladder D2cc and 70–75 Gy for rectal and sigmoid D2cc.^{1,2,14}

2.11 Conformity and Homogeneity Assessment

The **conformity index (CI)** was used to assess the relationship between the prescription isodose volume and the target volume. The **homogeneity index (HI)** was used to evaluate dose uniformity within the target. The **dose non-uniformity ratio (DNR)** was also assessed, where applicable.

These indices provided additional information regarding the quality of dose distribution and the extent of high-dose irradiation outside the target.¹

2.12 Toxicity Assessment

Acute treatment-related toxicity was assessed clinically according to the **Common Terminology Criteria for Adverse Events (CTCAE), version 5.0**.

The following treatment-related adverse effects were documented:

1. Urinary symptoms
2. Rectal symptoms
3. Vaginal mucosal reactions
4. Pelvic pain
5. Bleeding
6. Gastrointestinal symptoms
7. Genitourinary symptoms

Toxicities were graded according to CTCAE v5.0 from grade 1 to grade 5.

2.13 Statistical Analysis

Data were entered into a structured database and analyzed using statistical software. Continuous variables were expressed as **mean ± standard deviation (SD)** or **median with interquartile range (IQR)**, as appropriate based on the distribution of the data. Categorical variables were presented as frequencies and percentages.

The **Pearson correlation coefficient** was used for normally distributed continuous variables, whereas the **Spearman rank correlation coefficient** was used when the assumptions for Pearson correlation were not met. Correlation analysis was performed to assess the relationships between HR-CTV volume and OAR doses.

A **two-sided p-value <0.05** was considered statistically significant.

3. Results

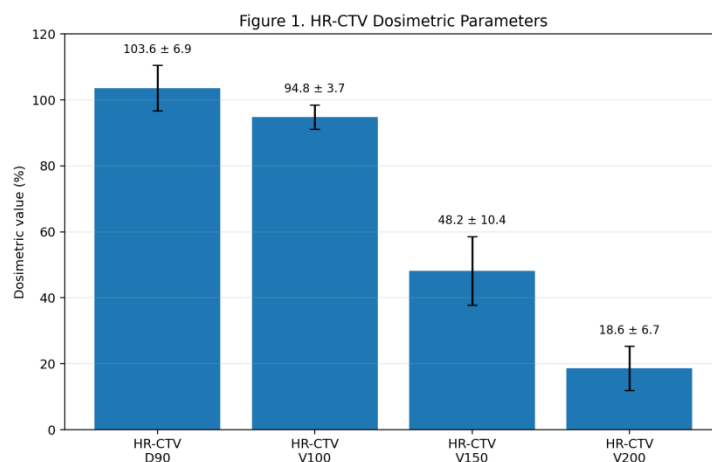


Figure 1. HR-CTV dosimetric parameters showing D90, V100, V150, and V200 values. Data are presented as mean ± SD.

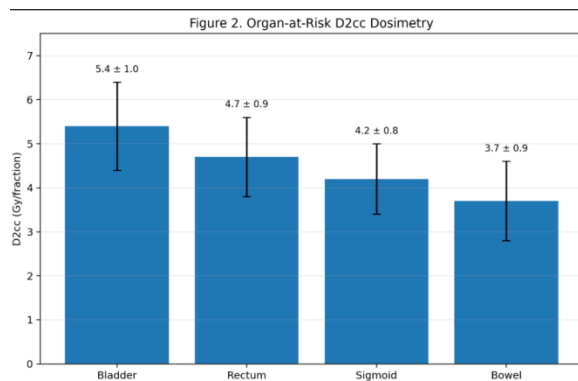


Figure 2. Dose to the most exposed 2 cm³ (D2cc) of the bladder, rectum, sigmoid colon, and bowel during interstitial brachytherapy. Data are presented as mean ± SD.

3.1 Baseline Characteristics

A total of 30 women underwent interstitial brachytherapy during the study period. The mean age was 54.7 ± 10.8 years, with an age range of 34–76 years. Cervical carcinoma was the predominant malignancy, accounting for 22 cases (73.3%). Vaginal carcinoma was present in five patients (16.7%), while three patients (10.0%) had vulvar malignancy.

Table 1. Baseline Characteristics of the Study Population

Variable	Number (%) / Mean $\pm$ SD
Total patients	30 (100)
Age, years	54.7 $\pm$ 10.8
Age range, years	34–76
Cervical carcinoma	22 (73.3%)
Vaginal carcinoma	5 (16.7%)
Vulvar carcinoma	3 (10.0%)
Squamous cell carcinoma	27 (90.0%)
Adenocarcinoma	3 (10.0%)
FIGO stage III	12 (40.0%)
FIGO stage II	10 (33.3%)
FIGO stage IVA	5 (16.7%)
Other/selected locally advanced disease	3 (10.0%)

3.2 Tumor and Treatment Characteristics

The mean HR-CTV volume was 62.4 ± 24.7 cm³. The mean number of implanted needles was 11.3 ± 3.2 , with a range of 6–17 needles. The mean number of active dwell positions was 76.8 ± 18.5 . The majority of treatment plans required individualized optimization because of irregular target geometry.

Table 2. Tumor and Implant Characteristics

Parameter	Mean $\pm$ SD
HR-CTV volume (cm ³)	62.4 ± 24.7
Number of needles	11.3 ± 3.2
Active dwell positions	76.8 ± 18.5
Number of fractions	3.0 ± 0.0
Dose per fraction (Gy)	7.0 ± 0.0
Total HDR dose (Gy)	21.0 ± 0.0
Implant procedure time (min)	48.6 ± 9.7

3.3 Target Dosimetry

The mean HR-CTV D90 was 7.1 ± 0.5 Gy, corresponding to $103.6 \pm 6.9\%$ of the prescribed dose. The mean D98 was 6.4 ± 0.6 Gy, while D50 was 8.5 ± 0.6 Gy. The mean V100 was $94.8 \pm 3.7\%$, indicating good target coverage. The mean V150 was $48.2 \pm 10.4\%$, while V200 was $18.6 \pm 6.7\%$.

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Table 3. HR-CTV Dosimetric Parameters

Parameter	Mean $\pm$ SD
D98 (Gy)	6.4 ± 0.6
D90 (Gy)	7.1 ± 0.5
D50 (Gy)	8.5 ± 0.6
V100 (%)	94.8 ± 3.7
V150 (%)	48.2 ± 10.4
V200 (%)	18.6 ± 6.7
D90 (% of prescription)	103.6 ± 6.9

Overall, 27 of 30 plans (90.0%) achieved HR-CTV D90 $\geq 100\%$ of the prescribed dose.

Three plans had D90 values between 90% and 100% because of proximity of the target to critical structures.

3.4 Organs-at-Risk Dosimetry

The mean bladder D2cc per fraction was 5.4 ± 1.0 Gy, while the mean rectal D2cc was 4.7 ± 0.9 Gy.

The corresponding mean sigmoid D2cc was 4.2 ± 0.8 Gy.

Table 4. OAR Dosimetric Parameters

OAR parameter	Mean $\pm$ SD
Bladder D0.1cc (Gy/fraction)	6.8 ± 1.2
Bladder D2cc (Gy/fraction)	5.4 ± 1.0
Rectum D0.1cc (Gy/fraction)	6.1 ± 1.1
Rectum D2cc (Gy/fraction)	4.7 ± 0.9
Sigmoid D0.1cc (Gy/fraction)	5.6 ± 1.0
Sigmoid D2cc (Gy/fraction)	4.2 ± 0.8
Bowel D2cc (Gy/fraction)	3.7 ± 0.9

The cumulative EQD2 values were calculated by combining EBRT and HDR brachytherapy doses.

3.5 Cumulative EQD2

The mean cumulative HR-CTV D90 EQD2 was 83.7 ± 5.8 Gy. The mean cumulative bladder D2cc EQD2 was 78.4 ± 8.6 Gy. The mean cumulative rectal D2cc EQD2 was 67.2 ± 6.9 Gy, while the mean sigmoid D2cc EQD2 was 64.8 ± 7.1 Gy.

Table 5. Cumulative EQD2 Parameters

Parameter	Mean $\pm$ SD
HR-CTV D90 EQD2 (Gy)	83.7 ± 5.8
Bladder D2cc EQD2 (Gy)	78.4 ± 8.6
Rectum D2cc EQD2 (Gy)	67.2 ± 6.9
Sigmoid D2cc EQD2 (Gy)	64.8 ± 7.1
Bowel D2cc EQD2 (Gy)	59.6 ± 7.4

Twenty-eight patients (93.3%) had cumulative bladder D2cc below 90 Gy. Twenty-nine patients (96.7%) had cumulative rectal D2cc below 75 Gy. Twenty-nine patients (96.7%) had cumulative sigmoid D2cc below 75 Gy.

3.6 Dosimetric Quality Indicators

The mean conformity index was 0.76 ± 0.08 , while the mean homogeneity index was 0.67 ± 0.09 . The mean dose non-uniformity ratio was 0.31 ± 0.07 .

Table 6. Plan Quality Indices

Parameter	Mean $\pm$ SD
Conformity index	0.76 ± 0.08
Homogeneity index	0.67 ± 0.09
Dose non-uniformity ratio	0.31 ± 0.07

The majority of plans demonstrated acceptable conformity with a relatively steep dose gradient outside the target.

3.7 Relationship Between Target Volume and OAR Dose

A positive correlation was observed between HR-CTV volume and rectal D2cc ($r=0.42$, $p=0.020$). A moderate

positive correlation was also observed between HR-CTV volume and bladder D2cc ($r=0.38$, $p=0.038$). The relationship between HR-CTV volume and sigmoid D2cc was weaker and did not reach statistical significance ($r=0.29$, $p=0.12$). These findings suggest that increasing target volume may increase the difficulty of achieving optimal OAR sparing.

Table 7. Correlation Between HR-CTV Volume and OAR Dosimetry

Variable	Correlation coefficient (r)	p-value
HR-CTV volume vs bladder D2cc	0.38	0.038
HR-CTV volume vs rectum D2cc	0.42	0.020
HR-CTV volume vs sigmoid D2cc	0.29	0.120

3.8 Acute Toxicity

The majority of patients experienced only grade 1–2 acute toxicity.

Grade 1 vaginal/pelvic discomfort was observed in 12 patients (40.0%), while grade 1 urinary symptoms occurred in seven patients (23.3%).

Grade 2 gastrointestinal toxicity occurred in four patients (13.3%).

No grade ≥ 3 acute gastrointestinal or genitourinary toxicity was recorded during the observation period.

Table 8. Acute Treatment-Related Toxicity

Toxicity	Grade 1	Grade 2	Grade ≥ 3
Pelvic/vaginal discomfort	12 (40.0%)	3 (10.0%)	0
Urinary symptoms	7 (23.3%)	2 (6.7%)	0
Rectal symptoms	5 (16.7%)	3 (10.0%)	0
Gastrointestinal symptoms	6 (20.0%)	4 (13.3%)	0
Vaginal bleeding	4 (13.3%)	1 (3.3%)	0

4. Discussion

Interstitial brachytherapy represents an important method of delivering highly conformal radiation to gynecological tumors with unfavorable anatomy or inadequate coverage by conventional intracavitary techniques. The present prospective observational study evaluated the dosimetric characteristics of 30 patients undergoing image-guided interstitial brachytherapy for female genital organ malignancies.

The principal finding was that the treatment plans provided satisfactory HR-CTV coverage while maintaining acceptable doses to the bladder, rectum, and sigmoid colon. The mean HR-CTV D90 was 103.6% of the prescribed dose, and 90% of patients achieved a D90 $\geq 100\%$. This finding is consistent with the principle that target coverage should be

prioritized while maintaining OAR doses within recommended limits.^{1,2,9–13} The mean V100 of 94.8% in the present study indicates that most of the target received the prescribed dose. GEC-ESTRO recommendations emphasize D90, D98, and volumetric target parameters as important measures of treatment quality because these parameters provide a more meaningful assessment of target coverage than traditional point-based prescriptions.^{9,10}

Interstitial implantation is particularly useful when tumor geometry is irregular. In such circumstances, individual needles can be positioned around and within the target, allowing the high-dose region to conform more closely to the disease. The ABS guidelines recommend three-dimensional treatment planning and careful assessment of the target and OAR dose-volume parameters in interstitial gynecological brachytherapy.^{1,2} In the present study, the mean bladder D2cc EQD2 was 78.4 Gy, while the

corresponding rectal and sigmoid D2cc values were 67.2 Gy and 64.8 Gy, respectively. These values were generally within the commonly accepted cumulative constraints of approximately 90 Gy for bladder and 70–75 Gy for rectum and sigmoid.^{1,2,14}

The importance of OAR dose-volume assessment has been demonstrated in clinical studies evaluating image-guided brachytherapy. Higher cumulative D2cc values, particularly for the rectum, bladder, and sigmoid, have been associated with increased risk of late toxicity. Therefore, maintaining adequate target coverage without unnecessarily increasing OAR doses is a major objective of treatment planning.

A positive correlation between HR-CTV volume and rectal D2cc was observed in the present study. This finding is clinically plausible because larger target volumes may require a greater number of active dwell positions and wider dose distributions, increasing the possibility of irradiation of adjacent organs. Similar challenges have been reported in studies of bulky vaginal and gynecological tumors where interstitial techniques have demonstrated advantages in reducing OAR doses while maintaining target coverage.^{8,15} The mean conformity index was 0.76, indicating reasonably good conformity of the prescription dose around the target. Interstitial brachytherapy can provide highly localized dose distributions because the source positions can be individually adjusted according to the three-dimensional target geometry.^{1,16}

The mean homogeneity index was 0.67. Although dose homogeneity is useful for describing treatment-plan characteristics, excessive emphasis on homogeneity should be avoided when it compromises target coverage or OAR sparing. In brachytherapy, heterogeneous high-dose regions immediately surrounding the implanted needles may be acceptable when they remain within the target volume.¹ The Indian Brachytherapy Society has emphasized the importance of appropriate applicator geometry, source reconstruction, optimization, and three-dimensional evaluation of dose-volume parameters.¹⁶ Particular attention is required during optimization because excessive dwell-time modulation can produce unintended hot spots or compromise the expected dose distribution. The present study also demonstrated that most patients experienced only mild-to-moderate acute toxicity. No grade ≥ 3 acute gastrointestinal or genitourinary toxicity was observed. However, these findings should be interpreted cautiously because the sample size was small and the study period was insufficient to comprehensively assess late toxicity.

Recent clinical evidence has further supported the feasibility of three-dimensional interstitial brachytherapy for gynecological malignancies, with acceptable target

dosimetry and OAR exposure when image-guided treatment planning is used.^{17,18} The findings of this study therefore support the role of systematic DVH-based assessment as an important component of quality assurance in interstitial brachytherapy. Rather than evaluating the prescription dose alone, treatment plans should be assessed using target coverage, OAR D2cc, EQD2, conformity, and dose distribution parameters.

Generalizability

The findings of this study may apply to tertiary care centers with access to three-dimensional image-guided interstitial brachytherapy and specialized gynecological oncology and radiation oncology services. The observed dosimetric outcomes may be particularly relevant to patients with anatomically challenging gynecological malignancies in whom conventional intracavitary brachytherapy may not provide adequate target coverage. However, the generalizability of these findings should be interpreted with caution because the study was conducted at a single tertiary care institution and included a relatively small and heterogeneous population comprising cervical, vaginal, and vulvar malignancies. Differences in patient anatomy, tumor characteristics, implant technique, treatment-planning systems, institutional expertise, and availability of image-guided brachytherapy may influence dosimetric outcomes. Therefore, the findings should be considered representative of the study setting and should be validated in larger, multicenter studies before being generalized to other treatment settings.

5. Conclusion

Three-dimensional image-guided interstitial brachytherapy demonstrated satisfactory dosimetric target coverage with acceptable doses to critical organs at risk in this study of women with gynecological malignancies. The majority of plans achieved an HR-CTV D90 close to or above the prescription dose while maintaining bladder, rectal, and sigmoid D2cc within generally accepted tolerance limits.

The use of DVH-based parameters, particularly HR-CTV D90, D98, V100, and OAR D2cc, provides a comprehensive method for evaluating interstitial brachytherapy plans. Individualized needle placement and optimization can improve dose conformity and facilitate OAR sparing, particularly in patients with bulky or anatomically irregular disease.

Limitations

The study has several limitations. First, the sample size was relatively small, with only 30 patients, which limits the

statistical power and generalizability of the findings. Second, the study was conducted at a single tertiary care institution, and treatment-planning practices may differ between centers. Third, the study focused primarily on dosimetric outcomes rather than long-term oncological outcomes. Fourth, the follow-up duration was insufficient to provide a robust assessment of late gastrointestinal, genitourinary, and vaginal toxicity. Fifth, the study included different female genital organ malignancies, and the heterogeneity of tumor site and stage may influence dosimetric parameters.

Recommendations

Larger prospective studies with longer follow-up are required to establish the relationship between dosimetric parameters and long-term tumor control and toxicity in patients receiving interstitial brachytherapy for female genital organ malignancies.

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List of Abbreviations

ABS – American Brachytherapy Society
CI – Conformity index
CT – Computed tomography
CTCAE – Common Terminology Criteria for Adverse Events
D2cc – Dose to the most irradiated 2 cm³ of an organ at risk
D50 – Dose received by 50% of the target volume
D90 – Dose received by 90% of the target volume
D98 – Dose received by 98% of the target volume
DNR – Dose non-uniformity ratio
DVH – Dose-volume histogram
EBRT – External beam radiotherapy
EQD2 – Equivalent dose in 2-Gy fractions
GEC-ESTRO – Groupe Européen de Curiethérapie–European Society for Radiotherapy and Oncology
HDR – High-dose-rate
HI – Homogeneity index
HR-CTV – High-risk clinical target volume
IGIMS – Indira Gandhi Institute of Medical Sciences
IQR – Interquartile range
ISBT – Interstitial brachytherapy
MRI – Magnetic resonance imaging
OAR – Organ at risk

SD – Standard deviation

Author Contributions

All authors reviewed the manuscript critically, approved the final version, and agreed to be accountable for all aspects of the work.

7. Ethics Approval

The study protocol received approval from the Institutional Ethics Committee of Indira Gandhi Institute of Medical Sciences (IGIMS), Patna, before commencement.

8. Consent

Written informed consent was obtained from all participants.

9. Funding

No external funding was assumed for this study.

10. Conflict of Interest

The authors declare no conflict of interest.

11. Data Availability

The data generated for this manuscript are illustrative. For an actual study, patient-level anonymized data should be made available according to institutional and journal policies.

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