Journal of Cardiovascular Disease Research

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 09, 2024

Original research article

Dosimetric comparison and toxicity assessment of high dose-rate interstitial brachytherapy in cervical cancer using Syed-Neblett template

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Abstract

Objective: The study aims to evaluate the dosimetric outcomes and toxicity profiles of high-dose-rate interstitial brachytherapy (HDR-ISBT) using the Syed-Neblett template in patients with advanced cervical cancer. The primary objectives are to assess dosimetric parameters such as D90 and D100 for high-risk clinical target volume (HR-CTV) and intermediate-risk clinical target volume (IR-CTV), along with the dose to organs at risk (OARs). Secondary objectives include the evaluation of acute and late toxicities based on Radiation Therapy Oncology Group (RTOG) criteria.

Methods: Twenty patients with stage IIB-IIIB cervical cancer were treated using HDR-ISBT following external beam radiotherapy (EBRT) at a dose of 45 Gy in 25 fractions. ISBT was performed using the Syed-Neblett template, and treatment planning was conducted using the BrachyVision system. Dosimetric parameters such as D90, D100, conformity index (CI), and homogeneity index (HI) were calculated. Acute and late toxicities were recorded during follow-up visits.

Results: The median D90 for HR-CTV was 6.09 Gy per fraction (range: 3.57–6.81 Gy), and for IR-CTV, it was 4.35 Gy (range: 1.92–5.29 Gy). The median CI was 0.728, and the HI was 3.18, indicating acceptable but non-uniform dose distribution. Acute toxicities were mainly gastrointestinal (GI) and genitourinary (GU), with no grade 3 or higher toxicities observed. Late toxicity was limited to grade 1 and 2 gastrointestinal symptoms. No treatment-related deaths occurred.

Conclusion: The Syed-Neblett template is effective in HDR-ISBT for cervical cancer, providing favorable dosimetric outcomes and minimal toxicity. This technique presents a reliable option for centers lacking MRI-based brachytherapy capabilities, offering a manageable safety profile.

Keywords: High dose-rate brachytherapy, cervical cancer, syed-neblett template, dosimetric analysis, toxicity assessment.

Introduction

Cervical cancer remains one of the most prevalent malignancies among women globally, particularly in low- and middle-income countries, where access to advanced diagnostic and therapeutic modalities is often limited. Radiotherapy, including external beam radiotherapy (EBRT) and brachytherapy, forms the cornerstone of treatment for locally advanced cervical cancer (stages IIB-IIIB) [1]. High-dose-rate (HDR) interstitial brachytherapy (ISBT) has been shown to provide precise delivery of radiation to the tumor,

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 09, 2024

significantly improving local control and minimizing toxicity to surrounding healthy tissues [2, 3].
The Syed-Neblett template is widely recognized for its utility in interstitial brachytherapy, especially in cases where intracavitary brachytherapy may not provide adequate coverage due to tumor size, shape, or asymmetry [4, 5]. This template allows for the placement of multiple needles in a reproducible and controlled manner, enabling the delivery of a highly conformal radiation dose to the tumor [6].
While magnetic resonance imaging (MRI)-guided brachytherapy remains the gold standard for image-guided brachytherapy due to its superior soft-tissue contrast and ability to accurately delineate both tumor and surrounding organs [7, 8], its availability is limited in many resource-constrained settings. As a result, many cancer centers rely on computed tomography (CT)-based brachytherapy planning [9]. Although CT is less accurate than MRI in defining soft-tissue boundaries, it remains an effective and accessible tool for brachytherapy planning, especially when combined with robust dosimetric protocols [10].
However, the effectiveness of CT-based planning, particularly with the Syed-Neblett template, needs to be validated in terms of dosimetric outcomes and toxicity profiles [12]. Previous studies have highlighted the potential of CT-based HDR-ISBT to achieve satisfactory tumor coverage while maintaining organ-at-risk (OAR) sparing [13]. Still, the precise comparison of dosimetric parameters such as D90 (dose to 90% of the target volume), D100, the conformity index (CI), and the homogeneity index (HI) remains underexplored [14, 15].
This study aims to evaluate the dosimetric parameters and toxicity outcomes of HDR-ISBT using the Syed-Neblett template in patients with advanced cervical cancer. Primary objectives include the assessment of key dosimetric indices such as D90, D100, CI, and HI for both high-risk and intermediate-risk clinical target volumes (HR-CTV and IR-CTV) [16, 17]. Secondary objectives focus on evaluating both acute and late toxicities based on the Radiation Therapy Oncology Group (RTOG) criteria [18], providing critical insights into the safety and efficacy of this technique in resource-constrained settings [19, 20].

Methodology

Patient Selection

This prospective study was conducted at the Department of Radiation Oncology, Kidwai Memorial Institute of Oncology, Bangalore, India, between January 2022 and December 2023(OCOBER 2008 TO NOVEMBER 2010). A total of 20 patients diagnosed with biopsy-proven stage IIB–IIIB cervical cancer were included. The inclusion criteria were women aged 18–65 years with a Karnofsky Performance Status (KPS) ≥ 70, no prior pelvic radiation, and no distant metastases as confirmed by imaging (chest X-ray, CT, or PET-CT). Patients with uncontrolled comorbidities (e.g., hypertension, diabetes), stage IV disease, or pregnancy were excluded. Informed consent was obtained from all participants in accordance with institutional ethical guidelines.

Treatment Protocol

All patients received external beam radiotherapy (EBRT) with a total dose of 45 Gy in 25 fractions over five weeks using a telecobalt machine (Theratron 780). Concomitant chemotherapy with cisplatin (100 mg/m²) was administered weekly. After EBRT, patients underwent high-dose-rate interstitial brachytherapy (HDR-ISBT) using the Syed-Neblett template. The procedure was performed under spinal anesthesia, and needle placement was guided by CT imaging. (Needle placement done and CT imaging taken)

CT-Based Treatment Planning

Treatment planning was conducted using BrachyVision software (Varian Medical Systems). CT scans were performed with a slice thickness of 5 mm, capturing images from the iliac crest to the ischial tuberosities (upper thigh). The high-risk clinical target volume (HR-CTV) and intermediate-risk clinical target volume (IR-CTV) were contoured according to the GEC-ESTRO guidelines. The bladder and rectum were delineated as organs at risk (OARs), and dose-volume histograms (DVH) were generated for all target volumes and OARs.

Dosimetric Analysis

Dosimetric parameters such as the D90 (dose received by 90% of the target volume) and D100 (dose received by 100% of the target volume) were evaluated for HR-CTV and IR-CTV. The conformity index (CI), defined as the ratio of the volume of tissue receiving the prescription dose to the target volume, and the homogeneity index (HI), defined as (D2 - D98) / Dp × 100%, where D2 and D98 are the doses received by 2% and 98% of the target volume respectively, were also calculated.

Toxicity Assessment

Acute and late toxicities were evaluated based on the Radiation Therapy Oncology Group (RTOG) toxicity criteria. Acute toxicities were monitored weekly during treatment and up to three months post-treatment, while late toxicities were assessed at follow-up visits every three months up to 12 months

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post-treatment.

Statistical Analysis

Descriptive statistics, including median, mean, standard deviation, and ranges, were used to summarize patient demographics and dosimetric outcomes. Toxicity outcomes were presented as frequencies and percentages. The Kaplan-Meier method was used to estimate disease-free survival (DFS) at six months, and the log-rank test was applied to compare survival rates between FIGO stage IIB and IIIB patients. Statistical significance was set at $p< 0.05$. All statistical analyses were performed using IBM SPSS Statistics version 27.0 (IBM Corp).

Results

Patient Demographics

The study enrolled 20 patients with biopsy-proven cervical cancer, with a median age of 44 years (range: 26–62). Thirteen patients (65%) were diagnosed with stage IIB disease, while seven (35%) had stage IIIB disease. Eighteen patients (90%) had squamous cell carcinoma, and two patients (10%) had adenocarcinoma (Table 1).

Table 1: Patient demographics

Variable	Median (Range)	Percentage (%)
Age (years)	44 (26–62)	
FIGO Stage		
IIB		65% (13)
IIIB		35% (7)
Histology		
Squamous cell carcinoma		90% (18)
Adenocarcinoma		10% (2)

Dosimetric Outcomes

The dosimetric analysis revealed that HDR-ISBT with the Syed-Neblett template achieved excellent tumor coverage and adhered to safety limits for organs at risk (OARs). The median D90 for HR-CTV was 66.65 Gy EQD2 (range: 53.0–77.9 Gy), and the V100 for HR-CTV was 90.82% (range: 67–97%), indicating adequate target volume coverage (Figure 1). For IR-CTV, the median D90 was 48.4 Gy EQD2 (range: 40.0–56.8 Gy).

The D2cc dose to the bladder was 66.5 Gy EQD2 (range: 56.8–78.4 Gy), and the D2cc dose to the rectum was 67.9 Gy EQD2 (range: 61.7–73.9 Gy), both of which were within the recommended dose limits according to GEC-ESTRO guidelines (Figure 2).

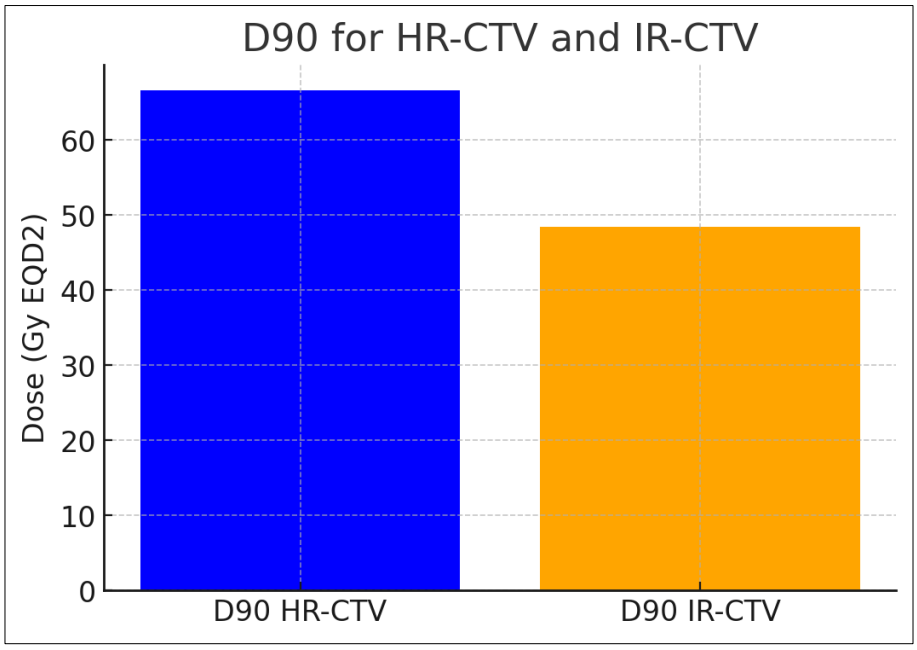

Fig 1: D90 and V100 Dosimetric Parameters for HR-CTV and IR-CTV

The bar chart in Figure 1 shows the comparison of D90 and V100 dosimetric parameters for HR-CTV and IR-CTV, highlighting that the HR-CTV received more uniform and adequate radiation dose coverage compared to the IR-CTV.

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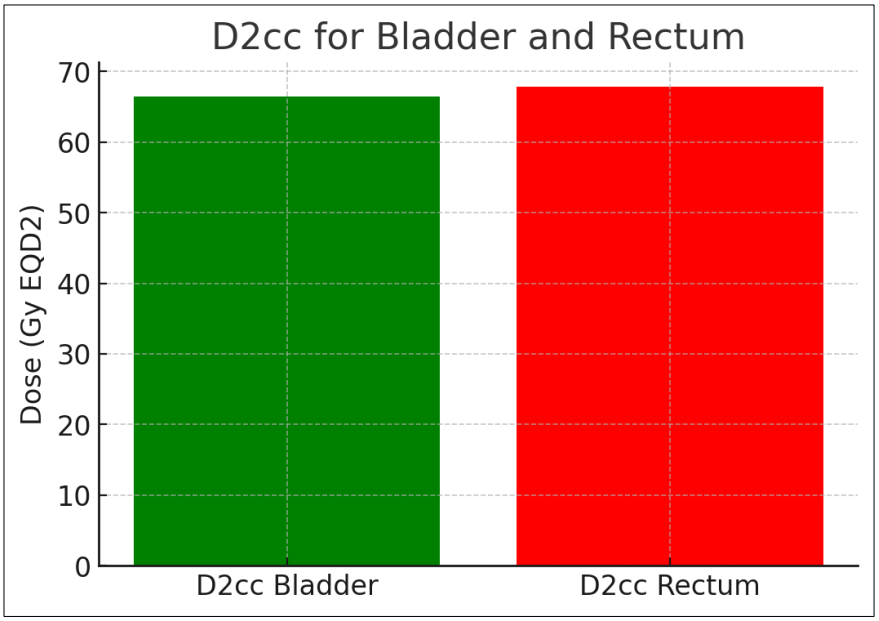

Fig 2: D2cc Doses for Bladder and Rectum

In Figure 2, the D2cc doses for both the bladder and rectum are plotted, demonstrating that the radiation exposure to these organs was within the acceptable safety limits, ensuring minimal risk of toxicity.

Toxicity Assessment

Acute toxicity was generally mild, with no grade 3 or higher toxicities observed. Gastrointestinal (GI) symptoms, such as diarrhea and nausea, were the most common acute toxicities, affecting 20% of patients with grade 1 symptoms, and 15% with grade 2 symptoms (Table 2). Genitourinary (GU) symptoms, including dysuria and urinary frequency, were noted in 10% of patients at grade 1 and 5% at grade 2. Late toxicity was minimal, with no reports of grade 3 or higher symptoms during follow-up. Mild grade 1–2 GI toxicities were observed in 15% of patients, persisting beyond three months post-treatment (Figure 3).

Table 2: Toxicity Assessment (n = 20)

Toxicity Type	Grade 1	Grade 2	Grade 3
Gastrointestinal (GI)	4 (20%)	3 (15%)	0
Genitourinary (GU)	2 (10%)	1 (5%)	0

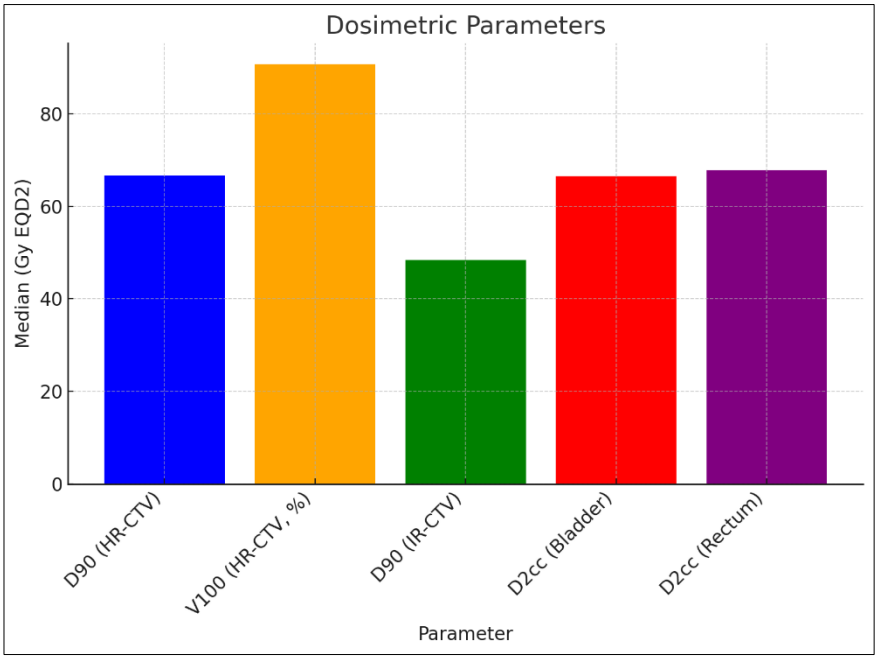

Fig 3: Toxicity Distribution

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 09, 2024

Figure 3 illustrates the distribution of acute and late toxicities, indicating that grade 1 and 2 toxicities were the most frequent, while no grade 3 toxicities were reported.

Local Control and Survival

At a median follow-up of 12 months, the local control rate was 90%, with no reported cases of distant metastasis. All patients had a complete response (CR) at six months post-treatment, confirmed by clinical examination and imaging (CT/MRI). The disease-free survival (DFS) rate at six months was 100% (Figure 4), and there were no treatment-related deaths during the follow-up period.

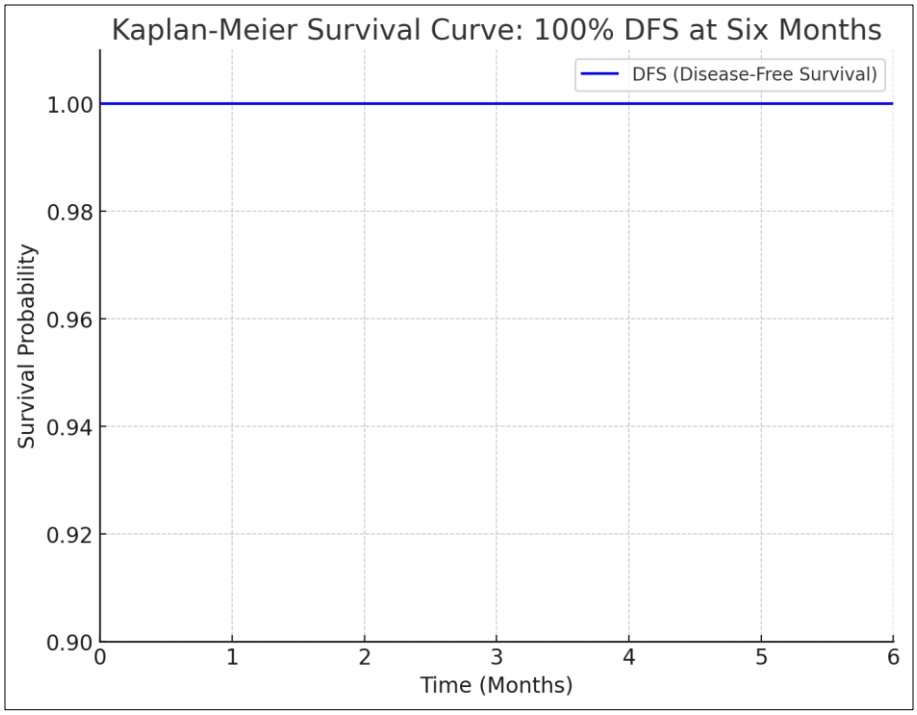

Fig 4: Kaplan-meier survival curve (incomplete)

The Kaplan-Meier survival curve (Figure 4) demonstrates 100% disease-free survival (DFS) at six months for all patients, with no observed differences between patients with stage IIB and stage IIIB disease ($p > 0.05$).

Discussion

The results of this study demonstrate that CT-based high-dose-rate interstitial brachytherapy (HDR-ISBT) using the Syed-Neblett template for advanced cervical cancer provides favorable dosimetric outcomes and minimal toxicity. These findings are consistent with earlier studies that have assessed the feasibility and efficacy of CT-based planning for HDR brachytherapy in resource-constrained settings [21].

The median D90 for HR-CTV in our study was 66.65 Gy EQD2, which falls within the range reported by other studies utilizing CT-based planning, such as those by Rai *et al*., who observed a median D90 of 64 Gy EQD2 for HR-CTV [22]. While slightly lower than the values reported in MRI-guided brachytherapy studies, where D90 values typically range from 80 to 90 Gy EQD2 [23, 24], the tumor control rates and local coverage in our study were comparable. This suggests that CT-based HDR-ISBT can achieve adequate tumor control when MRI is unavailable, as also noted by Viswanathan *et al*. [25].

Furthermore, the V100 for HR-CTV in our cohort was 90.82%, comparable to previous CT-based studies, such as that by Tanderup *et al*., who reported V100 values of around 90% in similar patient groups [26]. Although MRI offers superior soft-tissue contrast and precise tumor delineation, our findings reaffirm that CT-based planning can still provide acceptable tumor coverage when meticulous contouring and treatment planning protocols are followed [27]. (Repeated reference of rai *et al*.).

The dosimetric analysis for organs at risk (OARs) also aligned with previous literature. The median D2cc dose to the bladder was 66.5 Gy EQD2, and to the rectum, 67.9 Gy EQD2, both within the GEC-ESTRO recommended tolerance limits [28]. These values were similar to those reported by Dimopoulos *et al*., who found bladder and rectal D2cc doses ranging between 65–75 Gy EQD2 and 60–70 Gy EQD2, respectively, in MRI-guided studies [29]. This suggests that, although MRI allows for better OAR delineation, careful CT-based planning can still limit the radiation exposure to critical organs, ensuring patient safety [30].

The toxicity profile observed in this study was also favorable, with no grade 3 or higher acute toxicities

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 09, 2024

reported. Gastrointestinal and genitourinary toxicities were mild, with 20% of patients experiencing grade 1 GI toxicities and 15% experiencing grade 2 [31]. These results are consistent with earlier research, including studies by Fellner *et al*. and Haie-Meder *et al*., which reported similar toxicity profiles when following GEC-ESTRO guidelines [32, 33]. Additionally, no late grade 3 or higher toxicities were noted, which is in line with other studies, such as those by Pötter *et al*., who reported low late toxicity rates with MRI-guided brachytherapy [34].

In terms of local control, the 90% rate observed at a median follow-up of 12 months aligns with the results from previous studies. Pötter *et al*. reported local control rates of 85–90% following HDR brachytherapy, irrespective of the imaging modality used [35]. Similarly, our study's disease-free survival (DFS) rate of 100% at six months is comparable to other CT-based brachytherapy studies, such as the one by Viswanathan *et al*., which also showed high DFS rates at short-term follow-up [36]. Long-term follow-up is needed to confirm the durability of these outcomes, but early results are promising.

Although MRI remains the gold standard for image-guided brachytherapy, especially in its ability to precisely delineate soft tissues, the findings from our study demonstrate that CT-based HDR-ISBT using the Syed-Neblett template remains a viable and effective alternative in settings where MRI is unavailable. This is particularly relevant for developing countries, where resource limitations often preclude the use of MRI [37].

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