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FACTORS DETERMINING THE BLADDER AND RECTAL DOSE IN PATIENTS UNDERGOING INTRACAVITARY BRACHYTHERAPY-HIGH DOSE RATE (ICBT-HDR) IN CARCINOMA CERVIX

Oncology

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ABSTRACT

Purpose: To assess the dosimetric impact of bladder volume, bladder shape, and uterine size on organs at risk (OARs)—the bladder and rectum—in patients with carcinoma cervix undergoing high-dose-rate intracavitary brachytherapy (ICBT-HDR). **Material and Methods:** A prospective study was conducted on 30 patients with cervical cancer following external beam radiotherapy (EBRT). Each patient underwent CT-based simulation under four different bladder volume conditions: empty (0 mL), 100 mL, 200 mL, and 300 mL. Based on CT imaging, bladder shapes were categorised into four types: flat, ellipsoid, horseshoe, and globular. Following this, uterine dimensions were measured at Point A level to evaluate their potential influence on dose distribution. Treatment planning was performed using the Eclipse system, with a prescribed dose of 7 Gy to Point A. To assess organ-at-risk (OAR) exposure, the D0.1cc and D2cc dose parameters were calculated for both the bladder and rectum. **Results:** Mean bladder volumes were 71.9cc, 171.3cc, 261.9cc, and 360.6cc for the respective filling protocols. Bladder shape distribution was 15.4% flat, 21.4% ellipsoid, 32.1% horseshoe, and 30.9% globular. With increasing bladder volume, bladder D2cc increased from 7.1 Gy (empty) to 9.3 Gy (300 cc). Rectal doses showed variation with bladder filling, with D2cc ranging from 5.4-6.0 Gy. Larger uterine size (>4 cm) corresponded to lower organ doses, with bladder D2cc of 6.4 Gy and rectal D2cc of 3.7 Gy. **Conclusion:** Bladder volumes of less than 100 cc, flat and globular bladder shapes, and uterine size greater than 4 cm in the anteroposterior dimension were associated with significantly lower doses to both the rectum and bladder. These findings suggest optimal parameters for incorporation into ICBT-HDR planning in cervical cancer patients.

KEYWORDS

ICBT HDR, OAR, Bladder Shape, Bladder Volume, Uterine Size, Carcinoma Cervix, Brachytherapy

INTRODUCTION

Intracavitary brachytherapy (ICBT) is a cornerstone in the treatment of cervical cancer. The International Commission on Radiation Units and Measurements (ICRU) Report 38 (1985) established standardised definitions for reference bladder and rectal point doses during ICBT based on conventional two-dimensional radiography. (1) The advent of advanced imaging modalities such as CT and MRI have enabled a shift from traditional ICRU point doses to more precise dose-volume parameters. This advancement has significantly improved the understanding of dose-volume histogram (DVH) effects on organs at risk (OARs), particularly the rectum and bladder, enhancing treatment planning and toxicity assessment. (2). However, variations in intrinsic anatomical factors, such as bladder volume, bladder morphology, and uterine dimensions, can lead to significant shifts in applicator positioning, potentially altering the dose received by both the tumour and surrounding organs, adding to its complexity. Additionally, the limited research and reports on these factors in the literature emphasise the need for studies like ours to investigate their role in achieving optimal target doses while minimising exposure to OARs

MATERIAL AND METHODS

A prospective study was conducted, enrolling thirty patients with histologically confirmed cervical cancer classified as FIGO (International Federation of Gynaecology and Obstetrics) stage IIB–IIIB, following written informed consent. Patients initially received external beam radiotherapy (EBRT) to a total dose of 45 Gy in 25 fractions, along with weekly concurrent cisplatin chemotherapy (40 mg/m²) as per standard treatment protocols. Subsequently, all patients underwent high-dose-rate intracavitary brachytherapy (ICBT-HDR) in accordance with internationally established guidelines for brachytherapy research (3, 4). The ICBT procedure was performed using CT-compatible ring applicators to ensure precise treatment planning and dose delivery. Following applicator placement, CT simulation scans were acquired from the lumbosacral junction to the ischial tuberosity with a slice thickness of 3 mm under four different bladder filling conditions, as follows (5):

- Empty bladder (0ml)
- 100 mL normal saline filling
- 200 mL normal saline filling
- 300 mL normal saline filling

A total of 120 CT scans (30 patients × 4 bladder filling states) were obtained.

In accordance with GEC-ESTRO recommendations (6), the organs at risk (OARs), namely the bladder and rectum, were delineated. Following this, specific anatomical factors were analysed. Bladder morphology was classified into four distinct categories—flat, ellipsoid, horseshoe, and globular—based on CT imaging. Additionally, uterine dimensions were measured at Point A level, using standard anatomical reference points along the transverse ("x") axis and anteroposterior ("y") axis. Based on the anteroposterior diameter, uteri were further classified into three groups:

- <3 cm
- 3–4 cm

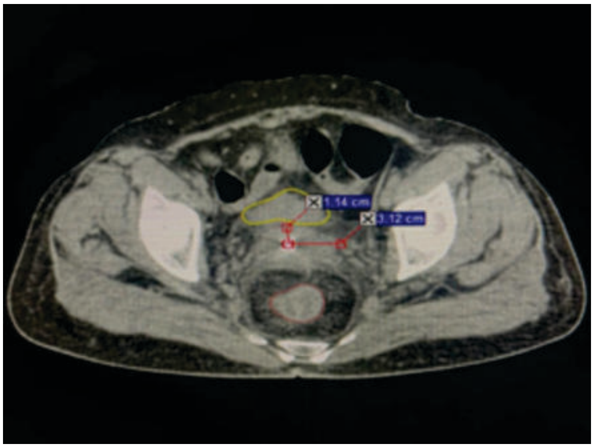

Fig. 1 shows the uterine size represented on both the x and y axes at the level of point A in the transverse section that requires colour in print.

A dose of 7 Gy was prescribed to Point A. Treatment planning was carried out using the Eclipse planning system, and the D0.1cc and D2cc dose parameters were calculated for both the bladder and rectum to assess OAR exposure.

RESULTS

Descriptive statistics was used to analyse and interpret the below-mentioned parameters:

Bladder Morphology

The distribution of bladder morphology among the cohort was as follows: Flat (15.4%), Ellipsoid (21.4%), Horseshoe (31.2%), and Globular (30.9%).

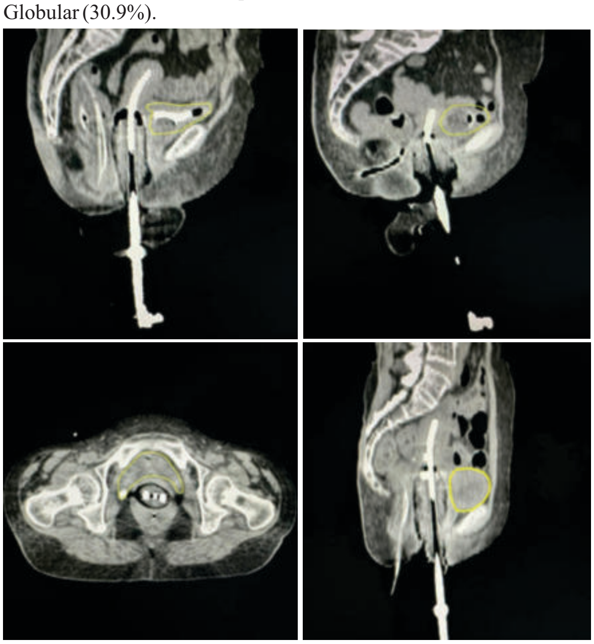

Figure 2 shows brachytherapy contouring and planning CT images representing various bladder morphologies, namely flat, ellipsoid, horseshoe, and globular, respectively. The bladder is represented by a yellow contour. Image that requires colour in print

Bladder Volume Analysis

The mean bladder volumes that were achieved with different filling protocols are as given below:

- Empty: 71.9cc
- With 100ml filling: 171.3cc
- With 200ml filling: 261.9cc
- With 300ml filling: 360.6cc

Dose Distribution with Bladder and Rectal Volumes:

Table 1 given below summarises the mean bladder and rectum doses corresponding to different bladder filling conditions.

Bladder Volume	Mean Bladder Dose (Gy)		Mean Rectum Dose (Gy)	
	D0.1cc	D2cc	D0.1cc	D2cc
Empty (71.9cc)	10.1	7.1	7.3	5.4
100ml	10.0	7.5	8.8	6.0
200ml	12.0	8.8	8.3	5.9
300ml	12.9	9.3	7.9	5.7

Bladder Dose Distribution Categorised by Bladder Shape:

Table 2 given below depicts the bladder dose distribution further categorised based on bladder morphology.

Bladder Shape	Mean D0.1cc (Gy)	Mean D2cc (Gy)
Flat	10.6	7.2
Ellipsoid	12.4	8.0
Globular	10.7	8.0
Horseshoe	11.2	8.5

Bladder and Rectum Dose Distribution Categorised by Uterine Size

Table 3 given below presents the bladder and rectal dose variations categorised by uterine anteroposterior (Y-axis) size under empty bladder conditions.

Uterine Size	Mean Bladder Dose (Gy)		Mean Rectum Dose (Gy)	
	D0.1cc	D2cc	D0.1cc	D2cc
<3cm	10.6	7.6	8.7	6.4
3-4cm	9.8	6.7	6.9	5.0
>4cm	9.6	6.4	5.0	3.7

DISCUSSION

Image-guided high-dose-rate (HDR) brachytherapy for cervical cancer is continuously evolving, offering improved precision in treatment delivery. Advances in imaging techniques, such as MRI and CT-based planning, have enhanced tumour delineation while minimising radiation exposure to surrounding organs at risk, leading to promising clinical outcomes (7). The dosimetric impact of various factors, including rectal filling, movements of the sigmoid colon, and vaginal packing, has been previously studied and documented (8). Similarly, bladder filling protocols have also been analysed and reported in literature. It has been reported that bladder volumes of 50 mL and 100 mL were well tolerated and resulted in reasonably reproducible bladder volumes during cervical brachytherapy (9).

Our study aims to explore any potential correlations between any additional anatomical parameters and brachytherapy dosimetry, further contributing to the understanding of factors influencing dose distribution and organ-at-risk exposure. Our study findings suggest that increased bladder volume generally correlates with higher bladder doses. Specifically, D2cc values increased from 7.1 Gy with an empty bladder to 9.3 Gy at 300cc filling. Notably, minimal bladder filling (<100cc) demonstrated more favourable dosimetric outcomes. With regard to rectal doses, bladder filling showed variable effects, with the highest rectal D2cc (6.0 Gy) observed at 100cc bladder filling, while empty bladder demonstrated relatively lower rectal doses (D2cc = 5.4 Gy). The shape of the bladder also appeared to impact dose distribution, with flat shapes showing lower doses (D2cc = 7.2 Gy) compared to horseshoe shapes (D2cc = 8.5 Gy), while globular shapes demonstrated intermediate doses comparable to flat shapes. Uterine dimensions showed an apparent inverse relationship with organ doses, where larger uterine size (>4 cm) corresponded to lower bladder doses (D2cc = 6.4 Gy) and rectal doses (D2cc = 3.7 Gy), suggesting potential better organ sparing with larger uterine dimensions.

The observations from this study may have relevance in treatment planning. Consideration could be given to maintaining bladder volume below 100 cc when feasible, and adopting patient positioning that promotes a flat or globular bladder shape might be ideas worth implementing. Cases with small uterine dimensions may benefit from additional attention during planning. Treatment teams could consider individualised bladder filling protocols based on patient anatomy, though further research is needed to validate such approaches. However, these factors may serve as a baseline for treatment planning. The implementation of image-guided approaches to verify bladder shape could be valuable, along with developing specific planning approaches for different anatomical scenarios.

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Several factors must be considered when interpreting these results. The relatively small cohort size of 30 patients may limit the statistical power for subgroup analyses. As this study represents a single-institution experience from a developing country, with findings specific to institutional protocols and equipment, its generalizability to other settings may be limited. Additionally, the lack of long-term clinical outcome correlation means that the relationship between these dosimetric findings and patient outcomes requires further investigation through additional studies with longer follow-up periods.

CONCLUSION

This study explores various anatomical factors that may influence ICBT-HDR treatment planning in cervical cancer. The findings suggest that bladder volumes less than 100cc, flat and globular bladder shapes, and uterine size greater than 4 cm in the anteroposterior dimension may be associated with lower doses to both the rectum and bladder. While these observations could potentially be incorporated into treatment planning approaches, such as the implementation of empty to low-volume bladder protocols and considering image-guided verification of bladder shape, further research with larger patient cohorts and long-term follow-up would be valuable to validate these preliminary findings and assess their impact on clinical outcomes.

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Conflict of Interest:

The authors declare no conflict of interest.

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