Original Article

Which Has a Superior Dosimetric Profile in Image-guided High-dose-rate Brachytherapy of Cervix – Tandem Ovoid or Tandem Ring Applicator?

Ramya Rangarajan
Department of Radiation Oncology, Government Royapettah Hospital, Chennai, Tamil Nadu, India

Abstract

Objective: This study aims to evaluate and compare the dosimetric performance of tandem ovoid (TO) and tandem ring (TR) applicators in image-guided high-dose-rate intracavitary brachytherapy for cervical cancer. **Materials and Methods:** Computed tomography datasets from 45 cervical cancer patients treated with either TO or TR applicators were analyzed. Dose-volume histograms were generated, and dose parameters for the target and organs at risk (OARs) were recorded for each insertion. Key dosimetric metrics, including doses to points A and B, D90 for the clinical target volume (CTV), and 2cc doses for the bladder, rectum, and sigmoid, were compared between the two applicator groups. **Results:** Dosimetric outcomes for target volumes showed no significant differences between TO and TR applicators, with comparable doses to point A ($P = 0.12$), point B ($P = 0.43$), and D90 CTV ($P = 0.10$). Similarly, OAR doses for the bladder ($P = 0.10$), rectum ($P = 0.15$), and sigmoid ($P = 0.10$) were statistically equivalent. However, TR applicators consistently delivered significantly higher doses to vaginal dose points (except anterior 5 mm points), highlighting a notable difference in dose distribution patterns. **Conclusion:** While both TO and TR applicators achieve similar dosimetric outcomes for the target and major OARs, the TR applicators are associated with significantly higher vaginal dose exposure. This distinction may have clinical implications, particularly for patients at risk of vaginal toxicity, and underscores the importance of applicator selection based on individual patient anatomy and treatment goals.

Keywords: Carcinoma cervix, high-dose-rate brachytherapy, tandem ovoid, tandem ring

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Introduction

Cervical cancer is the second most prevalent malignancy among females in our region, with an increasing incidence posing a significant public health challenge. Timely diagnosis is critical to preventing fatalities.[1] Unfortunately, many patients present at advanced stages, seeking treatment only when the disease has progressed significantly. For locally advanced cervical cancer, concurrent chemoradiation remains the gold standard treatment. Radiotherapy, a cornerstone of this approach, integrates external beam radiotherapy with brachytherapy to achieve optimal therapeutic outcomes.

The advent of three-dimensional (3D) image-based brachytherapy has revolutionized cervical cancer treatment, replacing traditional radiograph-based techniques. Historically, applicators such as Manchester, Paris, Fletcher Suit, and Stockholm were widely used for intracavitary brachytherapy. Today, the Manchester-/Fletcher-style applicators (tandem ovoid [TO], tandem cylinder, or colpostats) and the Stockholm-style applicators (tandem ring [TR]) dominate clinical practice. Tandem applicators are available in diverse configurations, including varying angles, lengths, and curvatures. Ovoids, cylinders, and rings are designed with differing outer and source path diameters, offering flexibility in treatment planning.

Notably, the source-to-vaginal surface distance changes with ovoid size in TO applicators but remains constant in TR applicators, irrespective of ring diameter. Furthermore, the source path orientation differs: TO applicators align parallel

Address for correspondence: Dr. Ramya Rangarajan, Department of Radiation Oncology, Government Royapettah Hospital, Chennai, Tamil Nadu, India.
E-mail: ramyarronco@gmail.com

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to the cervical canal, while TR and cylinder applicators align perpendicularly. These structural and functional differences significantly influence dose distribution and treatment efficacy.

Modern brachytherapy techniques also include personalized, patient-specific 3D-printed mold applicators[2-4] and combined intracavitary-interstitial applicators for addressing complex disease presentations, such as parametrial extensions.

Although previous studies have compared specific dosimetric parameters of TO and TR applicators,[5-8] there is a lack of comprehensive analysis encompassing all critical parameters, including dose to point A, dose to the target, dose to organs at risk (OARs), and vaginal dose points. This study aims to fill this gap by systematically evaluating all dosimetric parameters to determine the relative dosimetric advantages of the two most commonly used intracavitary applicators – TO and TR – in 3D image-guided brachytherapy for cervical cancer.

Materials and Methods

Patient selection

Patients selected for this study met the following criteria: they received brachytherapy using both TO and TR applicators in subsequent applications between January 2021 and December 2022. Eligible patients completed a course of external beam radiotherapy totaling 50 Gy in 2 Gy per fraction in 25 fractions, accompanied by weekly cisplatin treatments followed by intracavitary brachytherapy, 7 Gy per fraction in 3 fractions. Only those with available computed tomography (CT) datasets for review were included. Additionally, patients must have undergone the brachytherapy treatment regimen with both specified applicators. Those who completed the prescribed radiotherapy with only one of the two applicators were excluded from the study.

Procedure

Prior to the procedure, all patients underwent rectal preparation with a soap and water enema. The brachytherapy procedure was conducted under general anesthesia in the operating room. A urinary catheter was inserted, and the Foley bulb was filled with 3 mL of iodinated contrast and 4 mL of normal saline. The selected applicator (either TO or TR) was then inserted and secured in place. Anterior and posterior vaginal packing was performed before the patient was transferred to the simulation room.

Contouring and planning

Computed tomography (CT) scans with a slice thickness of 3 mm were obtained using a CT simulator (Somatom, Siemens, Erlangen, Germany). These images were then transferred to the treatment planning system (Nucletron, an Elekta company, Stockholm, Sweden). Contouring of target volumes and OARs followed the recommendations outlined by GEC ESTRO.[9] The volumes of the high-risk clinical target volume (HRCTV), bladder, rectum, and sigmoid were documented. A prescribed dose of 7 Gy was normalized to point A, defined as a point situated 2 cm above the distal end of the lowest source in the cervical canal and 2 cm lateral to the tandem. Dose-volume histograms were generated, and dose-volume parameters for the target (D90 CTV – dose received by 90% of the target volume) and OARs (D2cc – dose received by 2cc of bladder, rectum, and sigmoid) were recorded for each insertion.

Vaginal dose points were also recorded for both TO and TR applicator insertions. For TO applicators, vaginal dose points were specified on the surface of the ovoids and 5 mm from that point, while for TR applicators, they were specified at the 3, 6, 9, and 12 o'clock positions on the surface and 5 mm from the surface of the ring. Additionally, points at the level of the posteroinferior border of the pubic symphysis (PIBS), 2 cm above and 2 cm below this point represented the dose to the mid, upper, and lower vagina, respectively.

Statistical analysis

Statistical analysis was conducted using SPSS statistical package version 23 (IBM Corporation, New York, USA). Descriptive statistics, including mean, median, standard deviation, minimum, and maximum values, were computed to summarize the data. The normality of the data was assessed using the Shapiro–Wilk test. $P < 0.05$ from the Shapiro–Wilk test indicated that the data did not follow a normal distribution.

For normally distributed data, parametric tests were used, while for nonnormally distributed data, nonparametric tests were employed. Specifically, the Wilcoxon signed–rank test was used to evaluate the relationship between the dosimetric parameters of TO and TR applicators when the data were not normally distributed. A significance level of $P < 0.05$ was considered statistically significant.

Results

Tandem ovoid applicator

For patients treated with TO applicators, data from 45 individuals undergoing intracavitary brachytherapy were examined. Among them, 51.5% were diagnosed with stage IIB, 45.5% with Stage IIIB, and 3% with Stage IIA2. The median age was 52 years. The average volume of the CTV for TO applicator patients was 16 cc (±5). Bladder, rectum, and sigmoid volumes averaged at 77 cc (±60), 40 cc (±15.9), and 11 cc (±8.1), respectively. The mean doses to point A and point B were 6.6 Gy (±0.5) and 1.7 Gy (±0.2), respectively.

Tandem ring applicator

For patients treated with TR applicators, the average CTV volume was also 16 cc (±6). Bladder, rectum, and sigmoid volumes averaged at 58 cc (±25), 38 cc (±12.9), and 10 cc (6.7), respectively. The mean doses to point A and point B were 6.7 Gy (±0.61) and 1.8 Gy (±0.18), respectively.

Table 1 displays the doses delivered to point A, point B, and D90 CTV by both TO and TR applicators. Statistical analysis revealed no significant differences in these parameters between the two applicators. The Wilcoxon signed–rank test indicated nonsignificant disparities in point A dose ($z = -1.407$,

$P = 0.12$), point B dose ($z = -0.316$, $P = 0.75$), and D90 CTV dose ($z = -1.46$, $P = 0.144$) for both TO and TR applicators.

Table 2 presents the doses to OARs, namely D2cc bladder, rectum, and sigmoid. Similar to the target doses, there were no significant differences in the doses delivered to these organs between the two applicators. The Wilcoxon signed–rank test showed nonsignificant differences in D2cc bladder ($z = -1.633$, $P = 0.10$), D2cc rectum ($z = -0.863$, $P = 0.38$), and D2cc sigmoid ($z = -1.543$, $P = 0.58$) for both TO and TR applicators. Figure 1 illustrates the doses to the target and OARs for both TO and TR applicators.

Table 3 outlines the doses delivered to various vaginal dose points. TR applicators delivered significantly higher doses to all vaginal dose points except the posterior vaginal dose point, anterior 5 mm dose point, and posterior 5 mm vaginal dose point. The right vaginal point received the highest median dose for TO applicators, whereas the left vaginal point received the highest median dose for TR applicators. The anterior 5 mm vaginal point received the lowest dose from both TO and TR applicators. Statistical analysis revealed significant differences in the right vaginal point ($z = -3.472$, $P = 0.001$), left vaginal dose point ($z = -4.575$, $P = 0.000$), anterior vaginal dose point ($z = -4.765$, $P = 0.000$), 5 mm right vaginal point ($z = -4.141$, $P = 0.000$), and 5 mm left vaginal dose point ($z = -4.571$, $P = 0.000$) for both TO and TR applicators. However, there were no significant differences in the posterior vaginal dose point ($z = -0.582$, $P = 0.56$), 5 mm anterior vaginal dose point ($z = -1.564$, $P = 0.118$), and 5 mm posterior vaginal dose point ($z = -1.284$, $P = 0.199$) for both TO and TR applicators.

Table 4 illustrates the doses delivered to the upper, mid, and lower vagina. No significant differences were observed in the doses administered to these points. The Wilcoxon signed–rank test indicated nonsignificant differences in PIBS ($z = -0.785$, $P = 0.43$), PIBS + 2 ($z = -0.286$, $P = 0.77$), and PIBS − 2 ($z = 0.00$, $P = 0.87$) for both TO and TR applicators.

Figure 2 displays the doses delivered to the vaginal points for both TO and TR applicators.

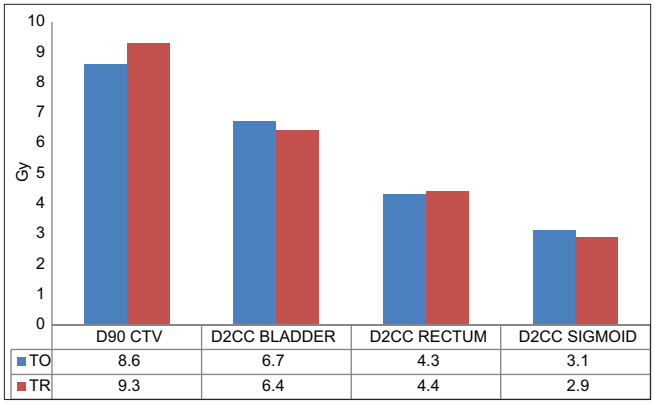


Figure 1: Chart showing the dose to the target and organs at risks for tandem ovoid and tandem ring applicators. CTV: Clinical target volume, TO: Tandem ovoid, TR: Tandem ring

Discussion

Magnetic resonance imaging-based image-guided adaptive brachytherapy has emerged as the standard of care for treating cervical carcinoma.[9-14] Critical factors influencing locoregional control include the HRCTV, the dose delivered to HRCTV, and the overall treatment duration.[15] Various applicators – TO, TR, tandem cylinder, hybrid intracavitary-interstitial, and interstitial – are employed for brachytherapy delivery.

TO applicators offer superior flexibility for lesions with vaginal extension, while TR applicators provide better radial loading, particularly for anterior and posterior forniceal disease extensions. TO applicators also enable asymmetric loading (e.g., small and large ovoids) for patients with distorted vaginal anatomy and allow adjustable spacing, unlike the fixed geometry of TR applicators. However, there are no established guidelines for applicator selection. Instead, the choice is dictated by patient anatomy, disease extent, clinician expertise, and applicator availability.

Table 1: Dose to the target

Parameters	TO (Gy), median	TR (Gy), median	*P*
Point A	7	7	0.12
Point B	1.8	1.8	0.75
D90 CTV	8.6	9.3	0.14

CTV: Clinical target volume, TO: Tandem ovoid, TR: Tandem ring

Table 2: Dose to organs at risks

Parameters	TO (Gy), median dose	TR (Gy), median dose	*P*
D2cc bladder	6.7	6.4	0.10
D2cc rectum	4.3	4.4	0.38
D2cc sigmoid	3.17	2.9	0.58

TO: Tandem ovoid, TR: Tandem ring, D2cc: Dose received by 2cc

Table 3: Vaginal dose points

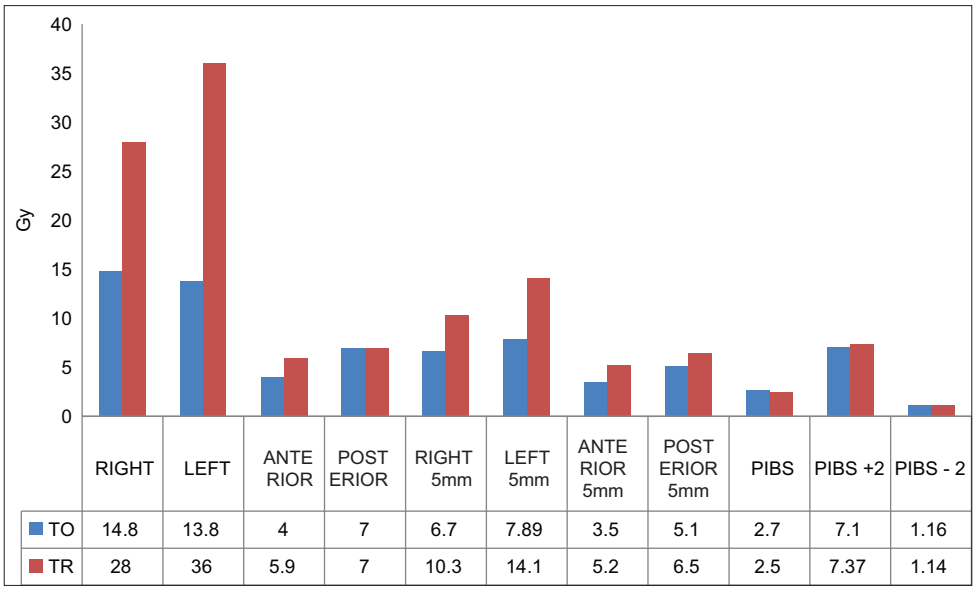
Parameters	TO (Gy), median	TR (Gy), median	*P*
Right	14.8	28	0.001
Left	13.8	36	0.000
Anterior	4	5.9	0.000
Posterior	7	7	0.560
Right 5 mm	6.76	10.38	0.0001
Left 5 mm	7.89	14.1	0.000
Anterior 5 mm	3.53	5.2	0.110
Posterior 5 mm	5.14	6.55	0.190

TO: Tandem ovoid, TR: Tandem ring

Table 4: Dose to upper, mid, and lower vagina

Parameters	TO (Gy), median	TR (Gy), median	*P*
PIBS	2.72	2.53	0.43
PIBS +2	7.14	7.37	0.77
PIBS −2	1.16	1.14	0.87

TO: Tandem ovoid, TR: Tandem ring, PIBS: Posteroinferior border of the pubic symphysis



	RIGHT	LEFT	ANTE RIOR	POST ERIOR	RIGHT 5mm	LEFT 5mm	ANTE RIOR 5mm	POST ERIOR 5mm	PIBS	PIBS +2	PIBS - 2
TO	14.8	13.8	4	7	6.7	7.89	3.5	5.1	2.7	7.1	1.16
TR	28	36	5.9	7	10.3	14.1	5.2	6.5	2.5	7.37	1.14

Figure 2: Dose to vaginal points for tandem ovoid and tandem ring applicators. TO: Tandem ovoid, TR: Tandem ring, PIBS: Posteroinferior border of the pubic symphysis

Among commonly used applicators, TO and TR designs have shown varied dosimetric outcomes in prior studies. Erickson *et al*.[16] reported higher bladder and rectal doses with TO applicators. Levin *et al*.[5] found that TO applicators treated larger volumes, while Prakash *et al*.[6] observed higher rectal doses with TR applicators. A tertiary care center study[7] found TO applicators delivered significantly higher D2cc doses to the rectum and sigmoid.

In contrast, our study revealed no significant differences in the doses delivered to HRCTV or OARs between the two applicators. However, TR applicators consistently delivered higher doses to vaginal dose points, almost double that of TO applicators at most points except the posterior, anterior 5 mm, and posterior 5 mm points. These findings align with EMBRACE I study results,[8] which showed higher D90 CTV doses with TR applicators (3.3 Gy higher than TO), although our study observed a more modest median difference of 0.7 Gy.

Clinical implications

Our findings suggest tailored applicator selection could enhance brachytherapy outcomes:

- TR applicators: Ideal for patients with forniceal and vaginal disease extensions, potentially improving local control and efficacy
- TO applicators: Preferable for patients with a complete response during brachytherapy, minimizing vaginal dose exposure and reducing radiation-induced toxicity, thereby improving quality of life.

These insights highlight the potential to refine treatment protocols by aligning applicator choice with disease presentation and patient characteristics, enhancing the precision and effectiveness of brachytherapy.

Study limitations

Our study's retrospective nature and small sample size limit the generalizability of the findings. In addition, this was a dosimetric study without analysis of clinical outcomes. Future research should focus on larger cohorts with adequate follow-up to establish the clinical impact of these dosimetric differences. Prospective studies incorporating quality of life assessments and patient-reported outcomes would provide a more comprehensive evaluation of applicator performance, guiding optimal clinical decision-making.

Conclusion

Our study indicates that TR applicators deliver higher doses to vaginal dose points compared to TO applicators, which may be advantageous for patients with forniceal and vaginal disease extension. Conversely, TO applicators might be preferable for patients with a complete response to limit vaginal dose exposure. The findings highlight the need for larger, prospective studies to further validate these results and assess their clinical implications. Incorporating patient-reported outcomes will be crucial for optimizing applicator selection in brachytherapy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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