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# Dosimetric evaluation of image based brachytherapy using tandem ovoid and tandem ring applicators

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ABSTRACT

*Aim:* The aim of the study is to evaluate the differences in dosimetry between tandem-ovoid and tandem-ring gynaecologic brachytherapy applicators in image based brachytherapy.
*Background:* Traditionally, tandem ovoid applicators were used to deliver dose to tumor in intracavitary brachytherapy. Tandem-ring, tandem-cylinder and hybrid intracavitary, interstitial applicators are also used nowadays in cervical cancer brachytherapy.
*Methods and materials:* 100 CT datasets of cervical cancer patients (stage IB2 – IIIB) receiving HDR application (50 tandem-ovoid and 50 tandem-ring) were studied. Brachytherapy was delivered using a CT-MRI compatible tandem-ovoid (50 patients) and a tandem-ring applicator (50 patients). DVHs were calculated and D2cc was recorded for the bladder and rectum and compared with the corresponding ICRU point doses. The point B dose, the treated volume, high dose volume and the treatment time were recorded and compared for the two applicators.
*Results:* The mean D2cc of the bladder with TR applicator was 6.746 Gy. TO applicator delivered a mean D2cc of 7.160 Gy to the bladder. The mean ICRU bladder points were 5.60 and 5.63 Gy for TR and TO applicator, respectively. The mean D2cc of the rectum was 4.04 Gy and 4.79 Gy for TR and TO applicators, respectively. The corresponding ICRU point doses were 5.10 Gy and 5.66 Gy, respectively.
*Conclusions:* The results indicate that the OAR doses assessed by DVH criteria were higher than ICRU point doses for the bladder with both tandem-ovoid and tandem-ring applicators whereas DVH based dose was lower than ICRU dose for the rectum. The point B dose, the treated volume and high dose volume was found to be slightly higher with the tandem-ovoid applicator. The mean D2cc dose for the bladder and rectum was lower with tandem-ring applicators. The clinical implication of the above dosimetric differences needs to be evaluated further.


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## 1. Background

Brachytherapy is an integral part of radiation treatment of cervical cancers. Traditionally tandem ovoid applicators have been used to deliver dose to the tumour. The applicators commonly used nowadays in delivering HDR intracavitary brachytherapy are tandem ovoid (TO) and tandem ring applicators (TR).[1] With the advent of image based brachytherapy, CT/MRI compatible intracavitary applicators are used in many centres. Combined intracavitary/interstitial implantation can be done with hybrid applicators.

When the vaginal vault does not accept ovoid or ring geometry, tandem cylinder applicators can be used. In addition to this, several customised applicators are also available to suit individual patient needs. In this study, we evaluated the differences in dosimetry between the most commonly used HDR gynaecological brachytherapy applicators, namely tandem ovoid and tandem ring applicators.

Tandem ring applicators can be used in patients with narrow vagina and in patients with obliterated vaginal fornices.[2,3] Better reproducibility is achieved with tandem ring applicators because of fixed geometry. Comparison of the dosimetric profile of the two applicators has been done earlier in several studies using orthogonal X rays.[4] Here, we used CT images to study the dosimetric parameters of the two applicators.

## 2. Aim

The aim of the study is to evaluate the differences in dosimetry between tandem ovoid and tandem ring gynaecologic brachytherapy applicators in CT based intracavitary brachytherapy of carcinoma cervix.

## 3. Methods and materials

Between January 2015 and September 2015, we evaluated 100 consecutive CT datasets of cervical cancer patients with FIGO stage IB2 to IIIB treated with HDR brachytherapy, out of which 50 datasets were tandem ovoid applicators and 50 were tandem ring applicators. TO applicators were CT MR compatible ones whereas TR applicators were metallic. All patients were treated with external beam radiotherapy to the whole pelvis to a dose of 50 Gy in 25 fractions. HDR brachytherapy was delivered with $Ir^{192}$ sources to a dose of 8 Gy to point A given one week apart.

The intracavitary application was performed under anaesthesia in the operating room. Bladder was catheterised and the Foley's bulb was filled with 7 ml dilute contrast solution. After sounding the uterus and serial dilatation of the cervix, the tandem of TO applicator was inserted followed by the ovoids. Dilatation was not required for the TR applicators because of thin stem of TR tandem.

After securing the applicators in place, careful vaginal packing was done to displace the bladder and rectum. In addition to posterior vaginal packing, a rectal retractor was used in all TR applications. For TR applications, 4 cm and 6 cm tandem lengths were commonly used. The most common size of the ovoid for TO applications was 2.5 cm. The most common tandem angle used for TO applicator was 30 degrees. 45 degree tandem angle was most commonly used for TR applicator.

CT simulation was taken for all patients using a CT simulator (Siemens, Somatom). 3 mm slices were taken and treatment planning was done using Oncentra planning system. Bladder, rectum and sigmoid colon were contoured and a 3D treatment plan was generated. Catheter reconstructions of the applicators were done. A standard loading pattern was followed for both tandem ovoid and tandem ring applicators. A step size of 2.5 mm was used for all applications.

Depending on the length of the tandem, the dwell positions namely 1,3,5,7,10,13,16,20, were activated for the tandem. For the TO applicator, 3,4,5,6 dwell positions were activated for the ovoids. The lateral dwell positions were activated for the ring applicator, namely 7,8,9,0, on the right side of the ring and 4,5,6,7 positions on the left side of the ring. A dose of 8 Gy was prescribed to point A for both TO and TR applications. Manual optimisation was done in select cases of TO and TR applications to meet GEC ESTRO constraints for organs at risk.

DVHs were generated and D2cc was recorded for the bladder, rectum and sigmoid. ICRU point doses were recorded for the bladder and rectum. Point B doses, 100% volume and 200% volume were recorded for both the applicators. Examples of coronal and sagittal and axial views of isodose distributions for the TO and TR applicators are shown in Figs. 1 and 2, respectively.

## 4. Statistical analysis

Statistical analysis was done using SPSS statistical package (version 20, IBM). Descriptive statistics, like mean and standard deviation, were calculated. Statistical analysis was done using unpaired student t test to assess the relationship between dosimetric values of TO and TR applicators. Significance was assessed at $p < 0.05$.

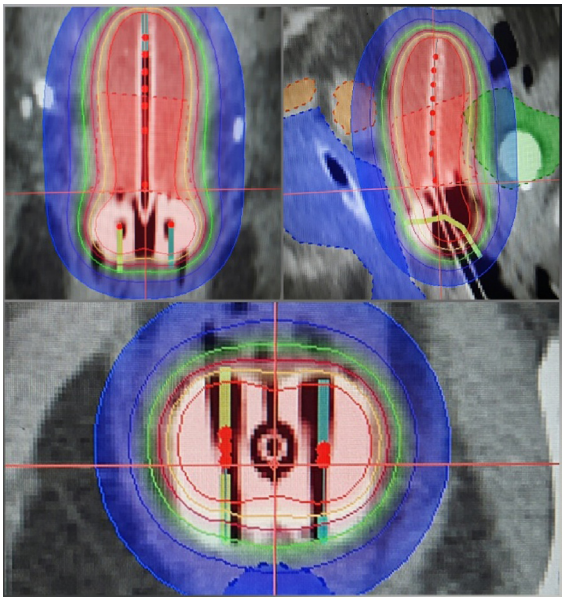

**Fig. 1 – Coronal, sagittal and axial views of isodose distributions of tandem ovoid applicators.**

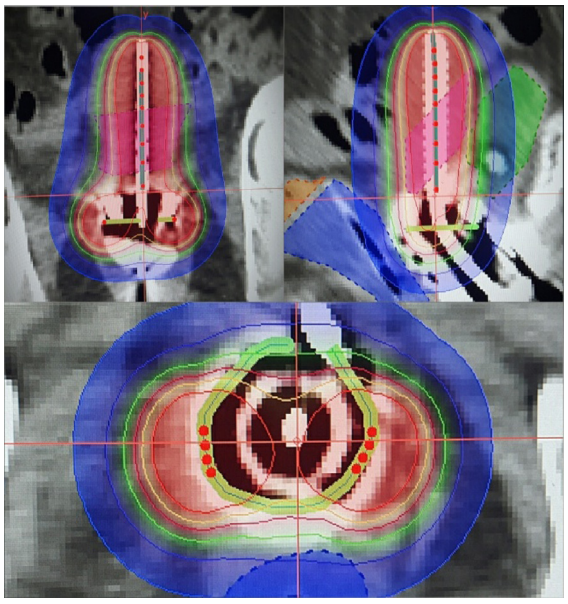

**Fig. 2 – Coronal, sagittal and axial views of isodose distributions of tandem ring applicators.**

## 5. Results

The average point B dose (Table 1) was significantly lower with TR applicator compared to TO applicator. This may be attributed to the length of tandem used in TR applicator. The most common tandem length used with TR applicator was 4 cm whereas the average tandem length with TO applicator was 5 cm.

50 TO applications were compared with 50 TR applications. The mean D2cc bladder dose was 6.74 ± 1.47 Gy with TR and 7.160 ± 1.68 Gy with TO applicators (Table 2). The mean ICRU point doses for bladder were 5.60 ± 1.68 Gy and 5.63 ± 2.2 Gy for TR and TO applicators, respectively. The mean D2cc rectal dose was 4.05 ± 1.08 Gy with TR and 4.79 ± 1.39 Gy with TO applicators. The mean ICRU rectal point doses were 5.10 ± 1.04 Gy and 5.66 ± 1.33 Gy, respectively, for TR and TO applicators. The mean D2cc sigmoid dose was 2.80 ± 0.60 Gy with the TR applicator and the mean D2cc sigmoid dose was 3.29 ± 0.72 Gy for TO applicator.

There were no significant differences in ICRU bladder point dose and D2cc bladder dose between TO and TR applicators. Rectum and sigmoid doses were found to be significantly higher with TO applicators as compared to TR applicators (Table 2). This may be attributed to the use of rectal retractors in TR applicators. The differences in dose to sigmoid may be attributed to the length of tandem used, namely a mean 5 cm tandem for TO applicator and 4 cm tandem for TR applicator. ICRU/2cc Ratio of Bladder and Rectum delivered by TO and TR applicators are 0.772, 0.847 and 1.179 and 1.265, respectively.

The point B doses, 100% isodose volumes and 200% isodose volumes (200%) were higher with the TO applicators (Table 3) which is in agreement with other studies reported in the literature.[10] Another interesting observation is that ICRU points *were lower* than the dose to 2 cc of the bladder and *higher* than the dose to 2 cc of the rectum with both TO and TR applicators.

## 6. Discussion

The advantages of TR applicators are easier placement and spatial reproducibility because of fixed geometry. Bahena et al.[5] studied the spatial reproducibility of the ring and tandem applicator. They found that the positional reproducibility of the applicator was dependent on the volume of the disease which in turn led to deviation of applicator during the early course of HDR brachytherapy. The positional variability of applicators with different fractions and their dosimetric impact were also analysed in several studies.

Ebruli et al.[8] studied factors that contribute to individual differences in applicator position with TR applicator. But no definitive conclusion was arrived at because of a small sample size. There are no direct comparisons between the position variability of TO and TR applicators in different fractions. Considering the intraindividual and interindividual variability in applicator positioning between different fractions due to differences in organ filling and applicator placement, individual imaging of each application is imperative regardless of the type of applicator used.

The dose distributions of TO and TR applicators were studied by Erickson et al.[4] Their study showed higher bladder and rectal doses with TO applicator and also a larger treatment volume by the TO applicator. The present study shows a significantly higher rectal and sigmoid dose with the TO applicator and a significantly larger treatment volume with the TO applicator. The bladder doses with TO and TR applicators were

**Table 1 – The average right and left point B doses delivered by TO and TR applicators are tabulated.**

| Point B | TO applicator | TR applicator | Difference in mean | *p* value |
|---|---|---|---|---|
| RT point B | 2.02 ± 0.17 Gy | 1.92 ± 0.15 Gy | 0.09 Gy | $p = 0.002$ |
| LT point B | 2.09 ± 0.17 Gy | 1.98 ± 0.12 Gy | 0.11 Gy | $p = 0.005$ |

**Table 2 – The average D2cc bladder, ICRU point dose bladder, average D2cc rectum, ICRU point dose rectum, D2cc sigmoid.**

| Dose to OAR | TO applicator | TR applicator | Difference in mean | *p* value |
|---|---|---|---|---|
| D2cc bladder | 7.16 ± 1.68 Gy | 6.75 ± 1.47 Gy | 0.41 Gy | 0.19 |
| ICRU bladder | 5.63 ± 2.2 Gy | 5.60 ± 1.68 Gy | 0.03 Gy | 0.91 |
| D2cc rectum | 4.79 ± 1.39 Gy | 4.04 ± 1.08 Gy | 0.75 Gy | 0.003 |
| ICRU rectum | 5.66 ± 1.33 Gy | 5.10 ± 1.04 Gy | 0.55 Gy | 0.02 |
| D2cc sigmoid | 3.29 ± 0.72 Gy | 2.80 ± 0.60 Gy | 0.48 Gy | 0.004 |

**Table 3 – The average treated volume and high dose volume of TO and TR applicators.**

| Dose volumes | TO applicator | TR applicator | Difference in mean | *p* value |
|---|---|---|---|---|
| 100% dose volume | $174.81 \pm 35.19\,cc^3$ | $146.63 \pm 19.1\,cc^3$ | 28.17 | 0.0001 |
| 200% dose volume | $65.23 \pm 17.45\,cc^3$ | $55.37 \pm 9.61\,cc^3$ | 9.85 | 0.0007 |

not significantly different in the present study. This may be attributed to the angle of the tandem used. The most common tandem angle used for the TR applicator was 45 degrees whereas it was 30 degrees for the TO applicator.

Short term clinical outcome using TO and TR applicators was studied by Ma et al.[6] Tumour coverage and short term toxicities were found to be equivalent in their study despite larger treated volume with the TO applicator. The treatment time was found to be shorter with TR applicator in some studies.[6] The optimal dwell positions for intracavitary brachytherapy was evaluated in a study[9] using a hypothetical 'matrix' applicator. The optimisation favoured dwell positions superior and closer to the cervix and closer to the perimeter of the vagina which was similar to the configuration of the ring applicator. The continuous source path within the ring offers additional flexibility for dose conformation compared to tandem ovoid applicators.

In our study, the dose was prescribed to point A. The clinical impact of the differences in treated volume between the two applicators can be better evaluated if CT based delineation of CTV[7,11] is done and by determining doses to the CTV. Considering the differences in point B doses between the two applicators and the larger treatment volume with TO applicator, should we use the TO applicators for patients with more advanced disease? Is TO applicator overtreating surrounding healthy tissue or is TR applicator underdosing tumour volume? The clinical implications of the dosimetric differences between the two applicators can only be determined by accurate delineation of target volumes with appropriate imaging modalities and by long term clinical follow up study.

## 7. Conclusions

Tandem Ovoid and Tandem Ring applicators are commonly used gynaecological intracavitary applicators. There are minor differences in dosimetry between the two applicators. The clinical situation should aid in choosing a particular applicator. TR is generally preferred for patients whose pelvic anatomy does not allow placement of two ovoids. Other clinical implications of the minor dosimetric differences should be evaluated in follow up studies.

## Conflict of interest

None declared.

## Financial disclosures

None declared.

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