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ORIGINAL ARTICLE

# Dosimetric comparison of ring and ovoid applicators

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## Summary

***Purpose:*** *To compare the dosimetry of different vaginal applicators used in the postoperative vaginal cuff irradiation.*

***Materials and methods:*** *In this model dosimetric study, standard ovoid applicator sets with 3 cap sizes (small/15 mm, medium/20 mm, and large/25 mm), and ring applicator sets with 3 diameter sizes (small/26 mm, medium/30 mm, large/34 mm) each with 3 different angles (30, 45, and 60 degrees) were used. Calculations were performed in Plato TPS (Treatment Planning System) as dwell positions of 2.5 mm step and equal dwell time for the sources. For ovoid applicators, the source positions 1-5 were loaded as active on each catheter, and in ring applicators the source positions 1-12, and 18-29; 1-14, and 19-32; 1-17, and 22-37 were loaded for small, medium and large ones, respectively. In addition to ICRU rectum reference point ($R_1$), 4 different rectum reference points (RPs) ($R_2$-$R_5$) were defined 1 cm apart. The vaginal cuff RP ($V_c$) was defined at 5 mm depth from the vaginal surface. The reference volume dose distribution was obtained according to the $V_c$ (100%) reference point. The width (w), max-min length (h, h'), and max-min thickness (t, t') of the reference isodoses were measured and max-min reference volume (v, v') was calculated.*

***Results:*** *$R_1$ dose was higher for ovoids (43.1%) than ring (28.6%), in all applicators. The increase of $R_1$ dose was parallel to the increase of ovoid/ring size (70-89%). As the applicator (ovoid-ring) size increased, max thickness of the reference isodose also increased (19-50%). For the largest size, the max increase was 62% (74.1-119.88 $cm^3$) and 93% (59.15-114.24 $cm^3$) for v and v', respectively. However, the magnitude of the reference volume was independent of the ring angle.*

***Conclusion:*** *In the present study it was found that when ring applicators were used according to recommended dwell positions, max rectum reference dose decreased in comparison to ovoid applicators; on the other hand, it should be noted that the size of the reference volume also decreased significantly.*

**Key words:** applicator, dosimetry, intracavitary brachytherapy

## Introduction

Brachytherapy is one of the most successful methods among the modern radiotherapy techniques in achieving the lowest doses to critical organs while giving the highest doses to tumor volume. Brachytherapy is being used since almost a century. In brachytherapy, morbidity can be lowered as much as possible with relevant modifications in treatment planning according to the tolerance doses of normal tissues. Thus, through the reduction of normal tissue volume and dose in the treatment volume, the rate of severe complications can be decreased. For this reason it is very important to determine the volume and dose of normal tissues accurately.

In many patients with cervical and endometrial cancer, postoperative radiotherapy is required [1-5]. In a selected group of early-stage endometrial cancer patients, adjuvant radiotherapy as exclusive brachytherapy produces local control with low morbidity [6-10]. In the treatment of advanced-stage cervical cancer with radical radiotherapy, brachytherapy is always used as a

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component of treatment [4,11-14]. ICRU (International Commission on Radiation Units and Measurements) published the Report 38 in 1985 which defined the rules for dose and volume specification for reporting intracavitary therapy in gynecology with the aim of forming standards and making the results in different institutions comparable [15]. In this report, some reference points were defined mainly for estimating the tumor dose and normal tissue doses. With the calculation of the doses to these reference points, it was aimed to predict the normal tissue doses and toxicity in a standardized manner and also to increase the tumor control rate. Gynecological brachytherapy has been performed using low or high dose rate radioactive sources and using various types of applicators [5,16-21]. The applicator type is chosen according to the anatomy of the patient and tumor. Ring applicator is useful especially when the vaginal fornices are absent or asymmetrical. In addition, it is sometimes preferred in clinical practice for its reproducible geometry and insertion easiness [4]. The applicator type influences reference dose-volume and dose of organs at risk.

In this study, two different models were formed i.e. ring applicators and ovoids which are used in vaginal cuff irradiation and their dosimetric comparison was carried out.

## Materials and methods

In this study, Nucletron high dose rate (HDR) Microselectron Device containing $Ir^{192}$, two different types of Nucletron vaginal applicator sets, and Nucletron Treatment Planning System were used.

There is a single $Ir^{192}$ source with stepping capability in Nucletron HDR Microselectron $Ir^{192}$ Device. This source with an activity of 10 Ci has 3.5 mm length and a diameter of 0.6 mm. It is contained in a capsule which has a length of 4.5 mm and a diameter of 0.9 mm. The capsule containing the source is placed at the end of a cable. $Ir^{192}$ source can be placed in 48 different dwell positions with 2.5 mm intervals in a single applicator with the help of a computer program and it can form an active source length of 120 mm. Moreover, it is possible to produce an active source length of 240 mm using 48 dwell positions with 5 mm intervals. The number of channels is 18. In order to optimize the dose distribution in the target volume, it is possible to modify both the dwell position and dwell time in the treatment planning system.

In this dosimetric study, "Fletcher" standard ovoid applicator set with 3 different cap sizes and ring applicator set were used. In the "Fletcher" standard ovoid applicator set, there were 3 different cap sizes: small (15 mm), medium (20 mm), and large (25 mm). The ring applicator set had 3 different angles (30, 45, 60 degrees) and each of the applicators with different angles had 3 different diameters: small (26 mm), medium (30 mm), and large (34 mm).

An application arrangement was prepared for each dosimetric model. In order to define source positions, dummy sources were placed in each catheter. Orthogonal localization AP (anterior-posterior) and LAT (lateral) films were obtained in the simulator. A total of 12 application models were formed, 3 for ovoid application, and 9 for ring application. The dwell times were equal and dwell positions were 2.5 mm apart in the treatment planning.

The source positions of 1-5 were loaded in each catheter in every ovoid applicator set. Active dwell positions were determined as lateral parts of the ring applicator in accordance with the American Brachytherapy Society's recommendations. The dwell positions were 1-12 and 18-29, 1-14 and 19-32, and 1-17 and 22-37, for small, medium and large ring applicators, respectively.

ICRU 38 rectum reference point was defined at 5 mm posterior to the posterior wall of vagina and named as $R_1$. In addition, 4 more rectum reference points were defined with 1 cm distance between the successive points and these were named as $R_2$-$R_5$. Rectum reference doses were calculated for every applicator type and size. For ring applicator, $R_1$ dose was calculated as the average of $R_1$ doses of 3 different angled ring applicators for each size. The same procedure was repeated for finding the $R_2$-$R_5$ doses for ring applicators. $R_{aver}$ was also determined taking the average of $R_1$-$R_5$ doses for both ring and ovoid applicators. The variation of rectum dose was evaluated with respect to the applicator type, ring angle and applicator size.

Reference dose point was defined at 5 mm depth from the vaginal surface and named as vaginal cuff ($V_c$) reference point ($V_c$=100%). Isodose distributions were obtained according to $V_c$ reference point in the applicator axis on coronal, sagittal and transverse oblique planes. Isodose plans of 12 applications were evaluated.

The width (w), max height (h), min height (h'), max thickness (t), and min thickness (t') were measured and max reference volume (v=hwt) and min reference volume (v'=h'wt') were calculated (Figure 1). The v and v' values for each size of ring applicator were obtained finding the average of the v and v' values of 3 different angles.

The variations in the dimensions and volumes of the reference isodose were evaluated in terms of applicator type, ring angle, and applicator size.

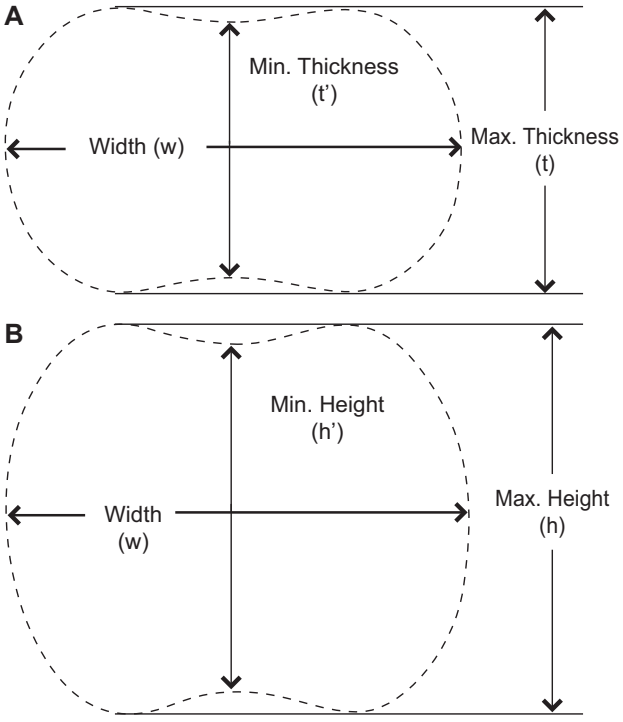
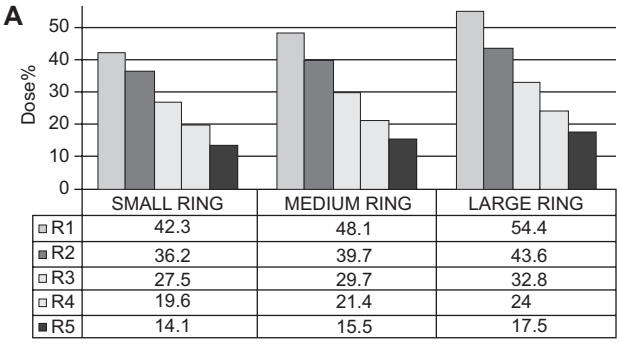
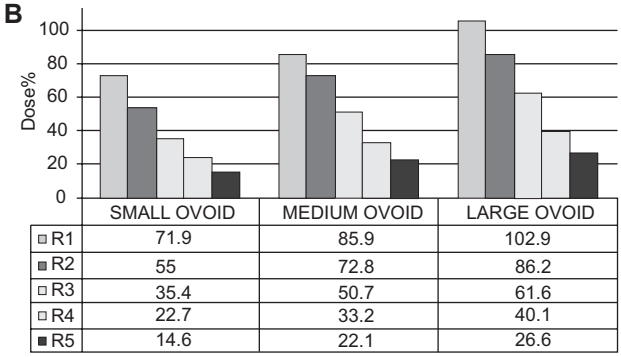



**Figure 1.** The volume parameters h, h', w, t, and t' v=h.w.t and v' = h'.w.t'. **A:** oblique coronal. **B:** oblique transverse.




| | SMALL RING | MEDIUM RING | LARGE RING |
|---|---|---|---|
| R1 | 42.3 | 48.1 | 54.4 |
| R2 | 36.2 | 39.7 | 43.6 |
| R3 | 27.5 | 29.7 | 32.8 |
| R4 | 19.6 | 21.4 | 24 |
| R5 | 14.1 | 15.5 | 17.5 |




| | SMALL OVOID | MEDIUM OVOID | LARGE OVOID |
|---|---|---|---|
| R1 | 71.9 | 85.9 | 102.9 |
| R2 | 55 | 72.8 | 86.2 |
| R3 | 35.4 | 50.7 | 61.6 |
| R4 | 22.7 | 33.2 | 40.1 |
| R5 | 14.6 | 22.1 | 26.6 |

**Figure 2. A:** % dose at R1-R5 rectum reference points for different size of ring applicators (normalized to reference point dose Vc= 100%). **B:** % dose of R1-R5 rectum reference points for different size of ovoid applicators (normalized to reference point dose Vc= 100%).

## Results

$R_1$ had the highest rectum reference dose in both applicator types (Figure 2).

Average and standard deviation of $R_1$ percent doses for 3 different ring angles were 42.3±4.2, 48.1±1.2, and 54.4±2.9, for small, medium and large ring applicators, respectively. It was found that $R_1$ rectum reference dose, which was normalized to $V_c$ reference dose, was independent of the ring angle.

The dependence of $R_1$-$R_5$ rectum reference doses to ring diameter was also evaluated. The percent doses of $R_1$-$R_5$ rectum reference doses for different sizes of ring and ovoid applicators are shown in Figure 2. $R_1$ and $R_{aver}$ doses increased in both applicator types depending on the applicator size.

For all applicator sizes, $R_1$ and $R_{aver}$ doses were higher in ovoid applicators than in ring applicators. $R_1$ percent dose was 42.3% for the small ring applicator, and 71.9% for the small ovoid applicator, whereas it was 54.4% for the large ring applicator and 102.9% for the large ovoid applicator. The increase rate of $R_1$ percent dose of small ring applicator with respect to that of small ovoid applicator was 70% and this increase rate reached 89% in the large applicators. $R_1$ dose increased as the size of the applicator increased in both applicator types. The maximum percent increase in $R_1$ dose was 43.1% and 28.6% for ovoid and ring applicators, respectively.

The w, h, h', t, t', v, and v' values calculated from the reference isodose for every applicator type and size are shown in Tables 1a and 1b.

The average and standard deviation of v value was 48.60 ± 3.98, 58.8 ± 1.64, and 74.1 ± 0.18 $cm^3$ for small, medium and large ring applicators, respectively. The magnitude of v was independent of ring angle.

The dependency of volume parameters to ring diameter is shown in Figure 3. Almost all dimensions increased in both applicator types as the applicator size increased. And that increase was also observed for v and v'. The maximum increase in v was 2.4 and 1.5 times in ovoid and ring applicators, respectively. The maximum increase in v' was 1.9 and 1.06 times in ovoid and ring applicators, respectively.

For all applicator sizes it was found that all dimensions except h and h' were higher in ovoid than in ring applicators. Although the dimensions h and h' were higher in ring applicators, v and v' values were higher in ovoid than in ring applicators.

The v value was 48.6 $cm^3$ and 50.13 $cm^3$ in the small ring and ovoid applicators, respectively. It was 74.1 $cm^3$ and 119.88 $cm^3$ in the large ring and ovoid

**Table 1a.** Volume and volume parameters of ring applicators

| | *Length (h) cm* | *Width (w) cm* | *Thickness (t) cm* | *Max. Volume (v) cm$^3$* |
|---|---|---|---|---|
| Small ring | 3.93 | 4.8 | 2.6 | 48.6 |
| Medium ring | 4.29 | 5.18 | 2.65 | 58.8 |
| Large ring | 4.75 | 5.71 | 2.73 | 74.1 |
| | *Length (h') cm* | *Width (w') cm* | *Thickness (t') cm* | *Min. Volume (v') cm$^3$* |
| Small ring | 3.8 | 4.8 | 2.47 | 44.2 |
| Medium ring | 4.05 | 5.18 | 2.38 | 49.8 |
| Large ring | 4.38 | 5.71 | 2.38 | 59.15 |

**Table 1b.** Volume and volume parameters of ovoid applicators

| | *Length (h) cm* | *Width (w) cm* | *Thickness (t) cm* | *Max. Volume (v) cm$^3$* |
|---|---|---|---|---|
| Small ovoid | 3.3 | 4.9 | 3.1 | 50.13 |
| Medium ovoid | 3.9 | 5.9 | 3.6 | 82.84 |
| Large ovoid | 4.3 | 6.7 | 4.1 | 119.88 |
| | *Length (h') cm* | *Width (w') cm* | *Thickness (t') cm* | *Min. Volume (v') cm$^3$* |
| Small ovoid | 3.2 | 4.9 | 3 | 47.04 |
| Medium ovoid | 3.7 | 5.9 | 3.5 | 76.41 |
| Large ovoid | 4.1 | 6.7 | 4 | 114.24 |

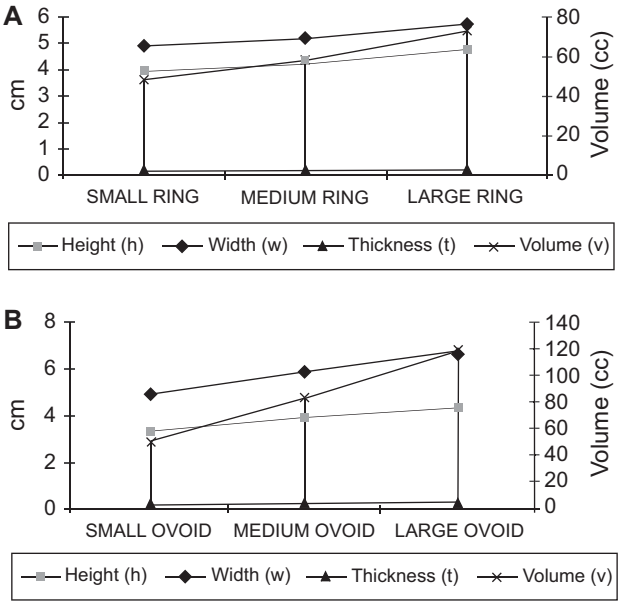



**Figure 3. A:** analysis of volume and volume parameters h, w, and t for different size of ring applicators. **B:** analysis of volume and volume parameters h, w, and t for different size of ovoid applicators.

applicators, respectively. The ratio of v value of small ovoid applicator to that of small ring applicator was 1.03 (50.13/48.6), and that ratio increased to 1.62 (119.88/74.1) for the large applicators.

## Discussion

As it is known, the applicator type, the source design and optimization techniques influence the magnitude of the reference volume and doses to organs at risk [22,23]. In practice, different applicator types are used in order to tailor treatment according to patient and tumor related factors (organ anatomy, tumor size and shape, etc).

In a study it was reported that rectum reference doses were affected from the applicator size [24]. In that dosimetric study, rectum reference point doses were found to increase as the applicator size increased in both ring and ovoid applicators.

$R_1$ point was detected as receiving the highest dose compared to other rectum reference points in our study. This finding supports that ICRU 38 rectum reference point is relevant in estimating the maximum dose to the rectum.

Noyes et al. from Guthrie Clinic compared the dosimetric properties of ring-tandem and ovoid-tandem applicators and found that the reference isodose volume was 1.5 times higher in the ovoid-tandem applicator [23]. Similarly, in our study, v and v' values were higher in ovoid applicators compared to ring applicators. As expected, reference isodose dimensions increased in relation to applicator size and, as a consequence, v and v' values increased. Since w, t, and t' values were higher in ovoid than in ring applicators, v and v' were also higher in ovoid applicators despite the fact that h and h' values were higher in ring applicators.

In this study it has been demonstrated that the maximum rectum reference dose was lowered when ring applicators were used instead of ovoid applicators. However, it should be noted that the reference

isodose volume also decreased with the use of ring applicators.

As shown in this study, ring and ovoid applicators have different dosimetric characteristics. In clinical practice these characteristics should be taken into account and optimization should be performed in brachytherapy treatment planning in order not to underdose the target volume while sparing normal tissues.

## References


1. Grigsby PW, Perez CA, Camel HM et al. Stage II carcinoma of the endometrium: Results of therapy and prognostic factors. Int J Radiat Oncol Biol Phys 1985; 11: 1915-1923.
2. Papavasiliou C, Yiogarakis D, Pappas J et al. Treatment of cervical carcinoma by total hysterectomy and postoperative external irradiation. Int J Radiat Oncol Biol Phys 1980; 6: 871-874.
3. Perkins PL, Chu AM, Jose B et al. Posthysterectomy megavoltage irradiation in the treatment of cervical carcinoma. Gynecol Oncol 1984; 17: 340-348.
4. Nag S, Erickson B, Thomadsen B, Orton C, Demanes JD, Petereit D. The American Brachytherapy Society recommendations for high-dose rate brachytherapy for the carcinoma for the cervix. Int J Radiat Oncol Biol Phys 2000; 48: 201-211.
5. Nag S, Erickson B, Parikh S, Gupta N, Varia M, Glasgow G. The American Brachytherapy Society recommendations for high-dose rate brachytherapy for carcinoma of the endometrium. Int J Radiat Oncol Biol Phys 2000; 48: 779-790.
6. Anderson JM, Stea B, Hallum AV, Rogoff E, Childers J. High-dose rate postoperative vaginal cuff radiation alone for stage IB in endometrial cancer. Int J Radiat Oncol Biol Phys 2000; 46: 417-425.
7. Elliot P, Gren P, Coates A et al. The efficacy of postoperative vaginal irradiation in preventing vaginal recurrence in endometrial cancer. Int J Gynecol Cancer 1994; 4: 84-93.
8. Noyes WR, Bastin K, Edwards S et al. Postoperative vaginal cuff irradiation using high dose rate remote afterloading: A phase II clinical protocol. Int J Radiat Oncol Biol Phys 1995; 32: 1439-1443.
9. Chen P, Gibbons S, Vicini F et al. Postoperative high dose rate intravaginal irradiation in endometrial cancer: a safe and effective outpatient treatment. Proceedings of the 37 Annual ASTRO Meeting. Int J Radiat Oncol Biol Phys 1995; 32(S1): 225.
10. Carey M, O'Connell G, Johanson J et al. Good outcome associated with a standardized treatment protocol using selective postoperative radiation in patients with clinical stage I adenocarcinoma of the endometrium. Gynecol Oncol 1995; 57: 138-144.
11. Perez CA, Kao MS. Radiation therapy alone or combined with surgery in barrel-shaped carcinoma of the uterine cervix (stage IB, IIA, IIB). Int J Radiat Oncol Biol Phys 1985; 11: 1903-1909.
12. Krishnan L, Cytacki EP, Wolf CD et al. Dosimetric analysis in brachytherapy of carcinoma of the cervix. Int J Radiat Oncol Biol Phys 1990; 18: 965-970.
13. Eifel PJ, Morris M, Oswoald MJ. The influence of tumor size and growth habit on outcome of patients with FIGO stage IB squamous cell carcinoma of the cervix. Int J Radiat Oncol Biol Phys 1993; 27: 127-128.
14. Lanciano RM, Won M, Coia LR et al. Pretreatment and treatment factors associated with improved outcome in squamous cell carcinoma of the uterine cervix: A final report of the 1973 and 1978 patterns of care studies. Int J Radiat Oncol Biol Phys 1991; 20: 667-676.
15. International Commission on Radiation Units and Measurements. Dose and volume specifications for reporting intracavitary therapy in oncology. ICRU Report 38, Bethesda, ICRU, 1985.
16. Ikeda H. Developments in brachytherapy. Gan To Kagaku Ryoho 1995; 22: 1317-1323.
17. Tore G, Aslay I, Dincer M et al. A new iridium applicator for vaginal vault irradiation. Eur J Gynaecol Oncol 1994; 15: 241-244.
18. Demanes DJ, Rege S, Rodriquez RR et al. The use and advantages of a multichannel cylinder in high-dose-rate brachytherapy. Int J Radiat Oncol Biol Phys 1999; 44: 211-219.
19. Anderson LL, Hofman MR. Minimal anisotropy in a remote afterloading vaginal applicator. Endocuriether Hypertherm Oncol 1993; 9: 59 (abstr).
20. Papadopoulou EZ, Morignat E, Reibel E et al. Iridium-192 high dose rate vaginal brachytherapy after hysterectomy for uterine cancers: Evaluation of a dedicated vaginal applicator. J Brachyther Int 1998; 14: 211-218.
21. Houdek PV, Schwade JG, Agabeytbol AA et al. HDR transvaginal brachytherapy: Applicator design and dosimetry. SELECTRON Brachyther J 1991; 2: 28-31.
22. Cetingoz R, Ataman OU, Tuncel N, Sen M, Kinay M. Optimization in high dose rate brachytherapy for utero-vaginal applications. Radiat Oncol 2001; 58: 31-36.
23. Noyes WR, Perest NE, Thomadsen BR et al. Impact of "optimized" treatment planning for tandem and ring, and ovoids, using high dose rate brachytherapy for cervical cancer. Int J Radiat Oncol Biol Phys 1995; 31: 79-86.
24. Senkus-Konefka E, Kobierska A, Jassem J, Badzio A. Patient-related factors determining geometry of intracavitary applicators and pelvic dose distribution during cervical cancer brachytherapy. Int J Radiat Oncol Biol Phys 1997; 37: 531-536.