

Impact of brachytherapy applicators geometry on dose distribution in gynaecological cancer

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Abstract

Objective: To evaluate the efficacy of suitable applicators for intracavitary brachytherapy to treat cervical cancer.

Methods: This study was conducted at the Bahawalpur Institute of Nuclear Medicine and Oncology, Bahawalpur, Pakistan, in February 2014. Dose distributions for Fletcher and ring applicators were analysed at target points according to recommended protocols using Abacus software. The doses to the organs at risk, i.e. bladder and rectum, were also focused. SPSS 16 was used for data analysis.

Results: A total of 40 patients' plans were considered. The mean absorbed dose at target point A was 6.87 ± 0.201 Gy in case of Fletcher applicator ($p=0.082$) and 6.79 ± 0.107 Gy in case of ring applicator ($p=0.001$). Absorbed dose at the target point was significantly higher for the Fletcher type applicators as compared to the ring applicators. However, the amount of doses at bladder and rectum were smaller for the Fletcher applicators.

Conclusion: Fletcher applicator was more effective in achieving a better dose distribution in gynaecological malignancies, resulting in better treatment outcome.

Keywords: Intracavitary Brachytherapy, Applicator Geometry, Dose, Gynaecological Cancer. (JPMA 66: 1566; 2016)

Introduction

The goal of radiotherapy is to deliver the maximum dose to the malignant tissues while minimising the exposure of surrounding healthy tissues. Nowadays radiotherapy alone or the combination with chemotherapy, brachytherapy or surgery is the major treatment technique for the cancer.¹

Brachytherapy is an integral component in any radiotherapy department. Intracavitary brachytherapy (ICBT) is the most commonly performed procedure, while interstitial brachytherapy is conserved for selected indication, e.g. narrow vagina or where there is no body cavity.² Therefore, different geometry of the applicators plays a crucial role in the ICBT.³

The subject of considerable research is to analyse the dose distribution scheme to the target by using Fletcher-style applicator and ring-type applicator. Various recommendations are available for intracavitary insertion technique, dosage schedule, dose prescription as well as for reporting of the full ICBT treatment procedure.⁴

Choice of the ICBT applicator is rather arbitrary and also depends upon the accessibility of the applicator type.⁵ The dose distribution in the brachytherapy is essentially

dependent on the inverse square law; so different types of dose distribution are attained with two different applicator systems, which may help to achieve higher therapeutic ratio.⁶ The anatomy of the patient and the extension of the disease also play a crucial role in the selection of a suitable applicator for the treatment. Different types of the applicators are being used to treat the cancer in brachytherapy. The size and specification of the applicators are allied to the dose delivered to adjacent organs.⁷ Radioisotopes are directly placed into the tumour or placed in the applicator which has been initially inserted into the body cavity close to the tumour.⁸ International working party for the early diagnosis and treatment of cervical cancer was introduced in 1972 by the co-operation of the International Atomic Energy Agency (IAEA) and the World Health Organisation (WHO) in developing countries.⁹

Assembly of the applicators depends upon the gynaecological malignant part. For example, vaginal treatment is instigated by the vaginal cylinder, and the cervical, uterine or endometrial cancer is initiated by the tandem and ovoid or tandem and ring applicator of various sizes. Tandem and ovoid devices are being used to treat gynaecological cancer such as uterine, cervical malignancies, etc. Numerous rigid forms of Fletcher, Henschke and ring applicators are also being used.¹⁰

In developed countries, image-guided brachytherapy (IGBT) is being used in many oncology centres, but in

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Pakistan both two- and three-dimensional treatment planning systems are used. The current study was planned to evaluate the dose distribution scheme of these different shape applicators to enhance the quality of treatment.

Materials and Methods

This dosimetric study was conducted in February 2014 at the Bahawalpur Institute of Nuclear Medicine and Oncology (BINO), Bahawalpur, Pakistan, where Fletcher and ring applicators are used for cervical cancer.

The Fletcher applicator was introduced in the early 1950s for treating carcinoma of the cervix. With the passage of time, some modifications have been made in the applicator to increase its suitability and to transfer the maximum dose to the target.¹¹ In this research work, Titanium Fletcher applicator of 6cm tandem length and intrauterine angle of 45° was used. The accessible Fletcher-style applicator (Varian Medical Systems) consists of two cylindrical vaginal ovoids and intrauterine tube. The ovoids lie at a plane almost perpendicular to the plane of the uterine tandem. Source stopping position (SSP) is kept at 0.5cm.

Ring applicator (Varian Medical Systems) consists of the uterine tandem and a vaginal ring. The ring and intrauterine tube are fixed to each other by a screw. The cap on the ring tube reduces the dose to vaginal mucosa. Fixed geometry is the advantage of ring applicator but curvature of the ring may cause difficulty for high dose rate (HDR) source to navigate.¹² In the current study, ring applicator of 6cm tandem length and angle of 45° was used, whereas ring diameter was 3.2 cm and SSP was kept at 0.5cm.

Treatment plans were generated using Abacus 3.0 treatment planning system (Varian Medical Systems) by digitising the dose reference point (DRP) and SSP for each plan. To perceive the suitability of both applicators, different optimising tools were applied. The basic parameters of the applicators for insertion like intrauterine, tandem length and angulations 45° were kept similar for both applicators. All suitable

considerations were used to maximise the dose to the target point A and to minimise at rectum, bladder and vaginal mucosa. After the insertion of applicator, anteroposterior and lateral (AP/LAT) view of digitally reconstructed radiographs (DRRs) were taken to content the rectum and bladder (organs at risk, or OARs).

The position of bladder and rectum was located and then reconstructed on the radiograph on Abacus treatment planning system. According to the Manchester system's five reference points — target point A (left and right), R for the rectum point, and B1 and B2 for the bladder — were reconstructed and dose was prescribed according to International Commission on Radiation Units and Measurements report (ICRU 38).^{13,14} Point A is defined as 2cm in the superior beside the tandem from the flange and 2cm lateral to the uterine duct.¹⁵ The dose fraction at point A, rectum and bladder was 7.00Gy, 5.00Gy, and 5.60Gy, respectively. Optimising constraints were used to deliver the prescribed dose to the point A and to secure the OARs. Approximately pear shape isodose curves were obtained for both applicators.

Dose distribution scheme of isodose curves was observed to compare both applicators. SPSS 16 was used to calculate the mean absorbed dose and standard deviation. T-test was used to find out the significance of the difference of absorbed dose. Absorbed dose to the target point was noted. Rectal and bladder dose was also observed to check out the suitability of the applicators. To check the level of significance, p-value was calculated with confidence interval (CI) at 95%. For all insertions, ICRU report 38 and American Brachytherapy Society (ABS) recommendations were kept in mind.¹⁴⁻¹⁶

Results

A total of 40 patients' plans were considered for this study. The mean absorbed dose at target point A was 6.87±0.201Gy in case of Fletcher applicator (p=0.082) and 6.79±0.107Gy in case of ring applicator (p=0.001). The respective values were 4.45±0.705Gy (p=0.038) and 4.80±0.410Gy (p=0.170) for rectum point, and 5.82±0.360Gy (p=0.085) and 5.89±0.181Gy (p=0.001) for

Table: Prescribed dose and Mean absorbed dose for both applicators.

DRP	Prescribed dose for 40 plans (Gy)	For Fletcher applicator			For Ring applicator			%diff
		Calculated Mean dose for 40 plans± std. error mean (Gy)	S.D	p-value	Calculated Mean dose for 40 plans± std. error mean (Gy)	S.D	p-value	
TA	7.00	6.87 ± 0.067	0.201	0.082	6.79 ± 0.033	0.107	0.001	1.17%
RP	5.00	4.45 ± 0.236	0.705	0.038	4.80 ± 0.130	0.410	0.170	7.50%
BP	5.60	5.82 ± 0.114	0.360	0.085	5.89 ± 0.059	0.181	0.001	1.19%

DRP: Dose reference point. TA: Target point A. RP: Rectum point. BP: Bladder point. SD: Standard deviation. %diff: Percentage difference.

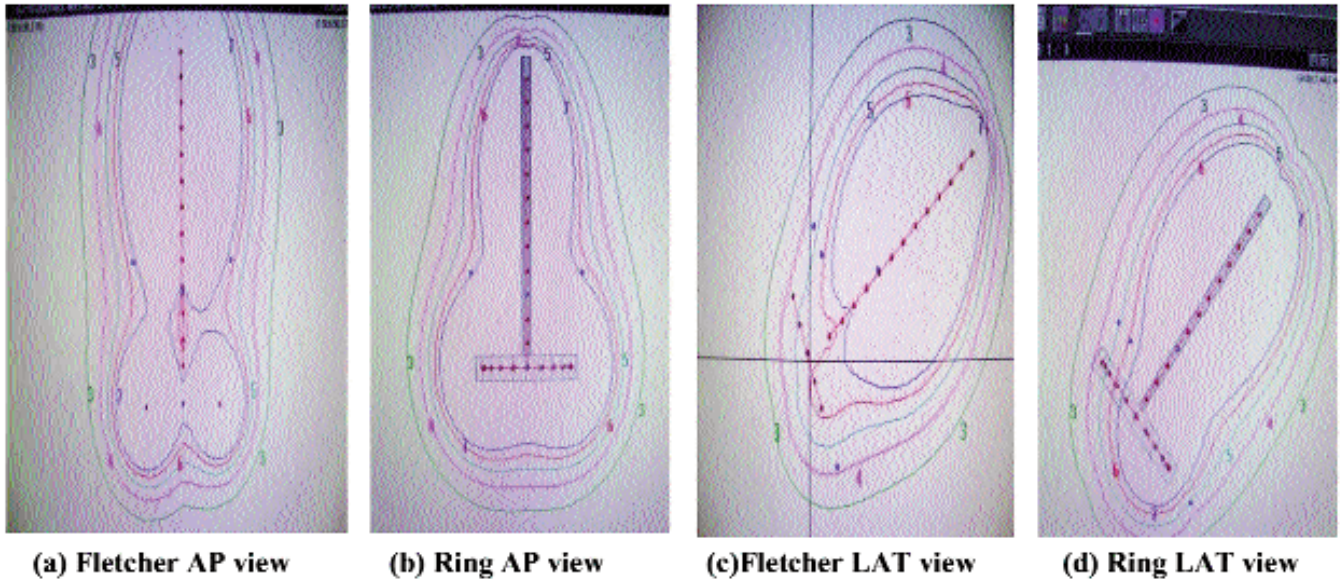
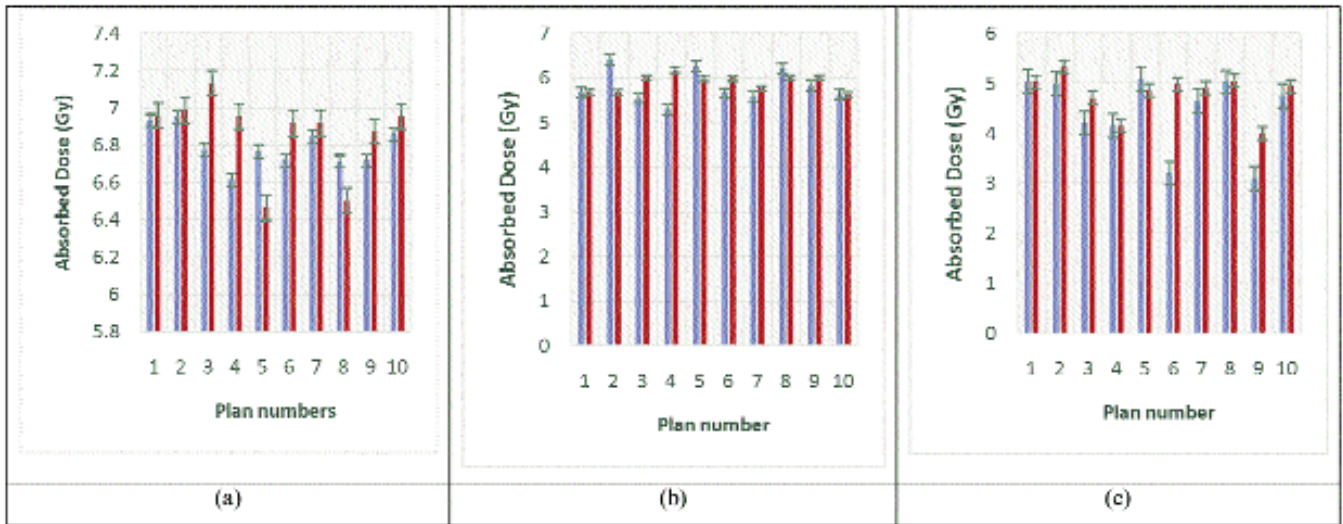


Figure-1: Comparison of AP/LAT isodose curves view of ring and Fletcher applicator.

AP/LAT: Anteroposterior and lateral.



● Fletcher applicator ● Ring applicator
Red points mention the SSP and blue represent the OARs.

AP/LAT: Anteroposterior and lateral
OARs: organs at risk
SSP: Source stopping position

Figure-2: Comparison of absorbed dose at (a) target point "A" (b) Bladder point (c) Rectum point.

bladder point (Table).

AP/LAT views of isodose curves showed that absorbed dose at target point was slightly different for both applicators but there was no statistically significant difference noted (Figure-1).

Each plan number contained an average of four treatment

plans. This represented 7.00 Gy was prescribed to the target point A, but slightly different absorbed dose was recorded in both Fletcher and ring cases. Suitable dose was transferred to the target point in case of Fletcher compared to the ring applicator (Figure-2a).

Moreover, 5.60Gy was the limited dose for the bladder, but in some cases for both applicators slightly higher or

lesser dose was transferred to the bladder. To chase the aim of every treatment planning, minimum dose should be delivered to the OARs, so according to the graphical representation less dose was transferred to the bladder in case of Fletcher as compared to the ring applicator (Figure-2b).

Furthermore, 5.00Gy was the limited dose for the rectum, but slightly higher dose was shifted to the rectum in case of ring applicator as compared to the Fletcher (Figure-2c).

Discussion

Geometry of the applicators plays a vital role in the dose distribution in brachytherapy.⁶ Both ring and Fletcher applicators are based on the Manchester system but their geometry is quite different. Curved shape of the ring applicator differs the scheme of dose distribution of both applicators.¹⁷ When these applicators are used in the same patient, they might show the different isodose curves. In this study, dose at the target point A and ICRU reference points (bladder and rectum) were noted. To compare the dose distribution around the OARs, isodose curves were also observed. According to the ICRU recommendation, dose was prescribed to the reference point and OARs were secured because these high-energy radiations produce the hydroxyl ion and damage the normal tissues.¹⁸

Sukhvir Singh et al. studied the effects of geometry of fixed- and flexible-shape applicators by using Abacus treatment planning software under the ICRU report 38 recommendations. They observed the dose variation at OARs (rectum and bladder). According to their results, in case of flexible geometry higher dose was delivered as compared to the fixed geometry applicator and isodose thickness was also higher in fixed geometry.⁶ Bishan Basu et al. compared the Manchester and Fletcher applicators. They used the dose volume data for the comparison. According to their results, Manchester applicator covered wider target volume as compared to the Fletcher.¹⁹ Tuncell et al. compared the ring and ovoid dose distribution to study the post-operative vaginal cuff irradiation, therefore no tandem was used. In their study, less dose was delivered to the rectum using ring as compared to ovoid; but the drawback of their study was that due to the absence of tandem, vaginal packing was not so better.²⁰

In the current study, the mean absorbed dose of all the patients was 6.79 ± 0.107 Gy ($p=0.001$) in case of ring applicator and 6.87 ± 0.01 Gy ($p=0.082$) in case of Fletcher applicator. Our findings showed that Fletcher readings were more reliable than ring applicator. For the comparison of bladder dose, the mean absorbed dose for

ring applicator was 5.89 ± 0.181 Gy ($p=0.001$) and 5.82 ± 0.360 Gy ($p=0.08$) for Fletcher applicator. In case of ring applicator higher dose was delivered to the bladder than Fletcher. Besides, average rectal dose of 4.80 ± 0.410 Gy dose was delivered to the rectum in case of ring applicator ($p=0.17$) and 4.45 ± 0.705 Gy in case of Fletcher applicator ($p=0.038$).

In case of Fletcher applicator, dose value at the target point was insignificantly less ($p=0.08$) or approximately equal to the prescribed dose, but in case of ring applicator absorbed dose was significantly less ($p=0.001$) than the prescribed dose value. To cure the OARs, minimum dose should be delivered to the rectum and bladder. Similarly for the rectum both applicators delivered less dose as compared to the prescribed dose, but in case of Fletcher applicator significantly less ($p=0.038$) dose was delivered to the rectum. On the other hand, both applicators delivered slightly higher dose to the bladder point than the prescribed dose, but ring applicator delivered significantly higher dose. There was no significant difference in the mean absorbed dose at point A for both applicators. Slightly higher dose was delivered in case of Fletcher applicator at target point A than ring applicator. The dose received by the OARs, e.g. the urinary bladder and the rectum, was different too. The dose received by the urinary bladder and rectum was significantly higher when ring applicator was used.

Conclusion

Absorbed dose at the target point was significantly higher for the Fletcher-type applicators as compared to the ring applicators. However, the amount of doses at bladder and rectum was less for the Fletcher applicators. Therefore, Fletcher applicator achieved a better dose distribution in gynaecological malignancies, which resulted in better treatment outcome.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

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