The Effect of Positional Movement of a Semiflexible Applicator on Dose Distrubutions in Low Dose Rate Brachytherapy for Cervical Carcinoma

Serviks Kanserinin Düşük Doz Hızlı Brakiterapisinde Yarı Esnek Bir Aplikatörün Hareketinin Doz Dağılımları Üzerine Etkisi

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ABSTRACT Objective: Current study aims to detect the movements of a semiflexible applicator (TÖRE's applicator) in the first 24 hours and to analyze its effect on the calculated point A, bladder and rectum doses in low dose rate brachytherapy (LDR-BT) applications. **Material and Methods:** Eighty films were evaluated on 18 cervical carcinoma patients (20 applications) who were treated with curative radiotherapy. The comparison of the reference points and doses at critical organs were performed by using a reference axis which was fixed to bony landmarks in the pelvis. To evaluate the movement of the applicator, distance of the upper point and lower point of the tandem to the reference axis were measured. Additionally, the angular deviation of the applicator was tested. **Results:** The movements of the upper point and lower point of the tandem in x, y, z axes were 5.30 ± 6.33 mm, 2.80 ± 2.24 mm, 6.65 ± 8.33 mm and 3.45 ± 4.32 mm, 3.75 ± 3.59 mm, 3.05 ± 3.08 mm, respectively. The mean differences were 3.30 ± 2.99º in α-angle and 5.65 ± 4.76º in β-angle. The mean percent dose changes in point A, bladder and rectum were 1.5±1.2%, 3.7±3.1%, 4.4±4.0%, respectively. **Conclusion:** Our study demonstrates that there are some movements of the applicator during LDR-BT, however these movements do not result in significant dose changes in target volumes and critical organs. Therefore, positional correction is not required. In conclusion, CT-compatible TÖRE's applicator that allows an advantage for CT-based 3D planning is useful and safe for brachytherapy.

Key Words: Brachytherapy; uterine cervical neoplasms

ÖZET Amaç: Çalışmamızın amacı, düşük doz brakiterapi (DDB) uygulamasındaki yarı-oynar aplikatörün ilk 24 saatteki hareketlerini taramak ve ölçümü yapılan A noktası, mesane ve rektumdaki etkilerini analiz etmektir. **Gereç ve Yöntemler:** Küratif radyoterapi alan 18 serviks karsinomu hastasında (20 uygulama) 80 film değerlendirildi. Referans noktalarının ve kritik organlardaki dozların karşılatırılması, pelviste kemik üzerinde merkez alınmış referans ekseni kullanılarak gerçekleştirilmiştir. Aplikatörün hareketini değerlendirmede ise referans eksenine bire bir uzaklıktaki en üst ve en alt noktalar arasındaki mesafe ölçülmüştür. Aplikatörün açısal sapması da ayrıca test edilmiştir. **Bulgular:** Hareketlerin x, y ve z eksenine bire bir uzaklıktaki en üst ve en alt noktadaki ölçümleri sırasıyla 5.30 ± 6.33 mm, 2.80 ± 2.24 mm, 6.65 ± 8.33 mm and 3.45 ± 4.32 mm, 3.75 ± 3.59 mm, 3.05 ± 3.08 mm bulunmuştur. Ortalama fark α-köşesinde 3.30 ± 2.99º, β-köşesinde 5.65 ± 4.76º'dir. Ortalama doz değişikliği yüzde olarak A noktasında, mesanede ve rektumda sırasıyla % 1.5 ± 1.2, %3.7 ± 3.1, %4.4 ± 4.0 olarak tespit edilmiştir. **Sonuç:** Çalışmamız, DDB sırasında aplikatörün bir takım yer değiştirmelerinin olduğunu fakat bu hareketlerin hedef hacim ve kritik organlarda kayda değer bir doz değişikliğine sebep olmadığını göstermiştir. Bu sebeple, çalışmamızda konumsal düzeltme gereksinimi olmamıştır. Üç boyutlu tedavi planlaması için avantajlı olan BT uyumlu TÖRE applikatörünün brakiterapi için kullanışlı ve güvenli olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Brakiterapi; uterin servikal tümörler

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The role of brachytherapy as a component of curative radiotherapy in patients with cervical cancer is well established.[1, 2] The main purpose of the intracavitary treatment to deliver a curative dose to the pri-

mary tumor while preventing the adjacent normal tissue as much as possible.[3, 4] The rapid fall of dose which is achieved by brachytherapy results in a high dose on tumor and lower doses on critical organs. However, unsuitable placement of sources increases the possibility of underdosing of the tumor or overdosing of the neighboring structures. Thus, the appropriate placement of the intracavitary applicator is necessary for a successful brachytherapy.[5]

Although many different applicator systems have been used over years, lowe dose rate brachytherapy (LDR-BT) is a well established method which isestablished on strong physical and biological basis.[6-10]

The relationship that is maintained between the brachytherapy applicator and the anatomic structures during the prolonged exposure time, clinically significant movement of the applicators and dose alterations during LDR-BT procedure have been studied only in a few reports.[11,12]

Since 1993, CT compatible and semi flexible TÖRE's applicator is used for LDR intracavitary brachytherapy in patients with cervical carcinoma at the Istanbul University Oncology Institute (Figure 1).

The aim of this study is to evaluate the movements' magnitude of the TÖRE's applicator and alterations in doses that may occur during LDR-BT and determine the effect of positional instability on treatment results.

FIGURE 1: TÖRE's applicator.

MATERIAL AND METHODS

PATIENTS

Between February 2001 and November 2001, we prospectively analyzed 80 localization films of 18 consecutive patients with uterine cervix carcinoma who were treated in our clinic. The median age of the patients was 54 years (range 32-71 years). Eleven patients were in International Federation of Gynecology and Obstretrics (FIGO) stage IIB, four patients in IIIB, one patient in IB, one in IIA, one in IVA. All patients were treated with two or four opposite pelvic fields irradiation of median 50.4 Gy (41.4–50.4 Gy), in 28 fractions (23-28fr.) by 15 MV photons. All fields that included whole pelvis were irradiated each day. LDR intracavitary brachytherapy applications were performed two weeks after the completion of external radiotherapy. The median reference dose which was given to point A was 40.0 cGy/hr (25.0-65.0). The total biological effective dose (BED) of external beam radiotherapy and LDR-BT ranged from 80 to 85 Gy_{10}. Sixteen patients received brachytherapy in one fraction. In two patients, applications were done in two fractions due to high doses at bladder point.

APPLICATOR AND BRACHYTHERAPY PROCEDURE

TÖRE's applicator consists of the following pieces: *The adjoining piece* is produced in three different sizes (small, 2.5; medium, 3.5; large, 4.5 cm in width) to suit vagina of different widths. The length, which is 1.5 cm, and the thickness, which is 1.2 cm, are the same for all three sizes. In the center of adjoining piece, there is a tandem canal with 4 mm in diameter, for the tandem to pass through. A rubber *fixing piece* is placed on the part that settles on the cervix orifice in order to adjust the length of the tandem according to intrauterine cavity depth. The fixing piece contains the radiological marker which fits onto the external os of the cervical canal. In the upper side of the adjoining piece, on either side of the tandem canal, there are two canals 4.2 mm in diameter and 18 mm in length that allow insertion of the vertical paracervical sources. The distance between the two lateral canals, with respect to size, is 2, 3 or 4 cm. Both the *tandem* and the *paracervical tubes* that are 2.5 mm

in diameter are made of semi flexible plastic and prepared so as to provide smooth insertion of the plastic inner tubes. At the end of each tandem and the paracervical tube, there is a lead pellet that serves as a radiological marker. *A rubber strap* is used in order to fasten the tandem and the paracervical tubes together along with a lavage tube. Unlike most of the commercially rigid applicators, this one is disposable and CT compatible.

A radiation oncologist performed the brachytherapy procedure to patients under general anesthesia. Rectovaginal examination was performed to assess tumor response after external irradiation. The cervix was marked with a radiopaque seed which was put in the portio at 12 o'clock level. Initially a Foley's catheter was inflated with 7 cm^3 of radio-opaque contrast. At the beginning of the procedure, the tandem was inserted to the uterine cavity. Since the tandem is only 4 mm in diameter, dilatation is usually not necessary. After that, adjoining piece and paracervical tubes were placed through the tandem. They were attached with a rubber strap and fixed onto the introitus of vagina with a suture. Rectal catheter with lead markers was placed. Radioactive source, Ir-192 wire, was loaded manually.

The reference dose was given to point A in brachytherapy. Point A was defined as 2 cm above the external cervical os and 2 cm lateral to the tandem, as Manchester System, while point doses of the bladder and rectum were calculated following ICRU Report No. 38 guidelines.[13] The treatment planning system which has been utilized was Theraplan 500 (Theratronix-Canada). The isodose distributions were plotted using the isocentric three film reconstruction techniques. Doses to points A, bladder and rectum were calculated. The bladder was empty when the films were taken. After dosimetry was done, bladder and rectal catheters were removed.

EVALUATION OF THE APPLICATOR MOVEMENT

Two sets of orthogonal films were taken isocentrically for every application. The first set of orthogonal films was taken after the radioactive sources (Ir 192, wire) were loaded in the applicator. The second set was taken at 24 hours later. The reason to evaluate the applicator movement one day after the placement was to correct the application and to see whether adjoining piece was turned clockwise or counter clockwise. While meassuring the amount of the movement of the applicator, the upper point (UPT) and the lower point of the tandem (LPT) were determined as reference points. The comparison of reference points and doses at critical organs was performed by using reference axis fixed to bony landmarks in the pelvis as followed:

1. In the coronal plane, x-axis was defined as a line joining the superior portion of the acetebulum, and y-axis was defined as a line bisecting the x-axis (Figure 2a).

2. In the sagital plane, z-axis was defined as a line joining the pubic symphysis and inferior border of the coccyx (Figure 2b).

3. The angle between the tandem and the paracervical sources' axis was determined as α angle (for shift of the tandem axis to the right or left of the midline) on the AP film (Figure 2a).

4. The angle between z-axis and the line joining the UPT to the pubic symphysis was determined as β angle (for tandem anteversion or retroversion) on the lateral film (Figure 2b).

X and Y coordinates of the reference points were measured on the AP films as positive and negative deviations to left-right or cranial-caudal of the applicator. Z coordinates were measured anterior or posterior deviations of the applicator on lateral films.

Vector analyses were done to find the average displacement of X, Y and Z coordinates of upper point and lower point of the tandem during the brachytherapy procedure. The average displacement was measured as ΔX, ΔY, ΔZ. ΔR was calculated with formula $\Delta R = (\Delta X^2 + \Delta Y^2 + \Delta Z^2)^{0,5}$. Angular deviations of the applicator were calculated with formulas $\Delta\alpha^o = |\alpha^o(\text{initial}) - \alpha^o(24 \text{ hours})|$ and $\Delta\beta^o = |\beta^o(\text{initial}) - \beta^o(24 \text{ hours})|$.

The doses that were given by brachytherapy were decided upon the parameters of the initial planning. To evaluate the dose variability which is

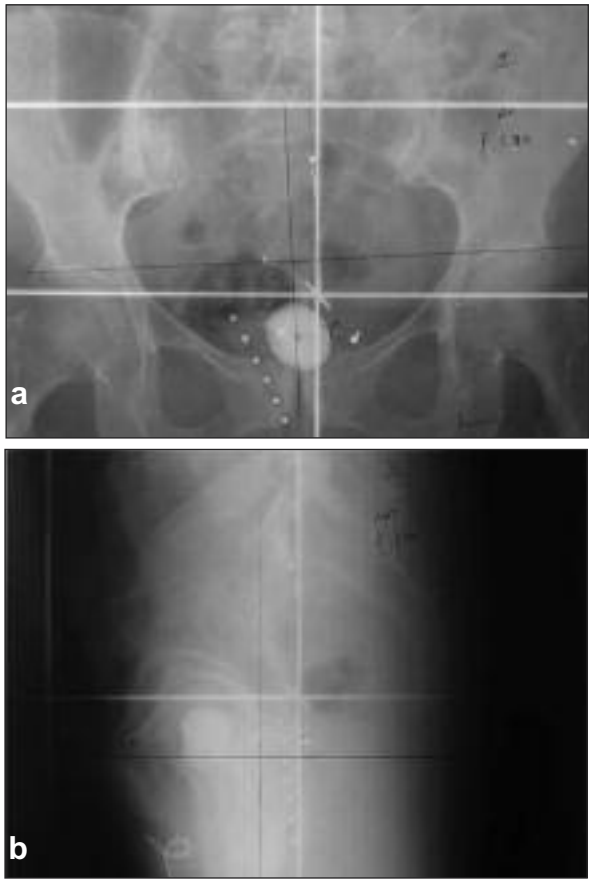


FIGURE 2: The applicator geometry parameters and the coordinate system used to measure applicator movements in (a) the anterior-posterior radiograph and (b) the lateral radiograph.

attributed to the applicator movement, we considered that the applicator was displaced immediately after the sources were loaded. Then, 24 hours after the application the doses were recalculated based on the changed parameters considering the whole treatment time.

STATISTICAL ANALYSIS

Statistical analysis was carried out to evaluate the significance of dose variations during LDR-BT procedure and its attribution to treatment results. Descriptive statistics were given for ΔX, ΔY, ΔZ and ΔR variables. Kolmogorov-Smirnov test was used for normality. Paired t-test was used to compare the means for point A, bladder and rectum doses. Spearman rank statistical analysis was performed to correlate the initial and 24 hours after the application doses for the point A, bladder and rectum. A p value <0.05 was considered as statistical significant. SPSS 16.0 statistical software was used for statistical analysis.

RESULTS

The median duration of the brachytherapy treatment was 79.3 (range 26.2-118.2) hours resulting in a median dose of 31.9 Gy (10-39). The median Ir 192 wire activity was 25.72 (16.69-34.67) $\mu Gymh^{-1}cm^{-1}$. Tandem length was 5 cm in five patients, 6 cm in nine patients, 6.5 cm in two patients, 7 cm in one patient and 7.5 cm in one patient. The adjoining piece was small in two patients, medium in 13 patients and large in three patients. In two patients with two brachytherapy applications, the tandem and adjacent pieces were the same with the first one.

The movements of the UPT in x, y, z axes were 5.30 ± 6.33 mm, 2.80 ± 2.24 mm and 6.65 ± 8.33 mm, respectively. The movements of the LPT in x, y, z axes were 3.45 ± 4.32 mm, 3.75 ± 3.59 mm and 3.05 ± 3.08 mm, respectively .The mean differences were 3.30 ± 2.99º in α-angle and 5.65 ± 4.76º in β -angle. The differences in the coordinates and angles of the tandem are shown in Table 1a.

On vector analysis, the median shift was 6.96 mm (3.61-32.83 mm) for the UPT and 6.36 mm (2.00-16.76 mm) for the LPT (Figure 3, Table 1b). The observed variance of β and α–angle is shown in Figure 4.

The mean total doses from external radiotherapy and intracavitary brachytherapy that have been calculated on point A, the bladder and the rectum were 81.38 ± 5.73 Gy, 72.72 ± 7.73 Gy and 68.24 ± 5.19 Gy for the initial dosimetry, respectively. After 24 hours, recalculated doses were 81.16 ± 5.43 Gy, 71.14 ± 8.47 Gy and 67.07 ± 4.43 Gy, respectively (Table 2).

For total treatment, the dose difference was statistically significant on the bladder point ($p< 0.05$), but not on the rectum and point A. The brachytherapy dose variances on point A, bladder and rectum for every patient are shown in Figures 5-7.

Statistical analysis was done to correlate the prescribed doses at the initial planning and 24 hours after sources were loaded. Scattergrams were

TABLE 1A: Variations found in Cartesian coordinates of upper and lower point of the tandem during LDR brachytherapy procedure.

Ref..P	Coordinates	Mean abs. dif.± SD (n=20)	Median (minimum- maximum) (n=20)
UPT (mm)	ΔX	5.30 ± 6.33	2.50 (0.00-20.00)
	ΔY	2.80 ± 2.24	2.50 (0.00-8.00)
	ΔZ	6.65 ± 8.33	3.50 (0.00-31.00)
LPT (mm)	ΔX	3.45 ± 4.32	2.00 (0.00-14.00)
	ΔY	3.75 ± 3.59	3.50 (0.00-14.00)
	ΔZ	3.05 ± 3.08	2.00 (0.00-10.00)
Δα°		3.30 ± 2.99	2.50 (0.00-11.00)
Δβ°		5.65 ± 4.76	4.50 (0.00-16.00)

Ref.P: Reference points, UPT: Upper point of tandem, LPT: Lower point of tandem.

TABLE 1B: Variations found in vector analysis of the reference points of tandem during LDR brachytherapy procedure.

Vector	Ref..P	Mean dif.± SD (n=20)	Median (minimum- maximum) (n=20)	%95 CI for medians
ΔR	UPT (mm)	10.64 ± 8.93	6.96 (3.61-32.83)	2.05 – 11.87
	LPT (mm)	7.47 ± 4.42	6.36 (2.00-16.76)	3.93 – 8.79

plotted to show the dose variables in points A, bladder and rectum (Figures 8-10).

The horizontal axis represents the prescribed dose in the second planning done 24 hours after the application, and the vertical axis represents the initial prescribed dose. For point A, the correlation was 0.96. However, in the bladder and rectum, the correlations of the values were 0.81 and 0.62, respectively.

The mean dose change ratios on point A, bladder and rectum were 1.5 ± 1.2%, 3.7 ± 3.1% and 4.4 ± 4.0%, respectively.

When the parametrium was involved, the applicator was deviated to the involved site in 65% of the cases. If there was bilateral parametrium invasion or no invasion at all, the applicator was in the center in 71% of the patients. In one patient whose uterus was retrovert, the tandem was deviated backwards.

DISCUSSION

Intracavitary brachytherapy improves outcome dramatically and so it is the most important component of definitive radiotherapy for cervical cancer.[14] Radiotherapy should include an adequate

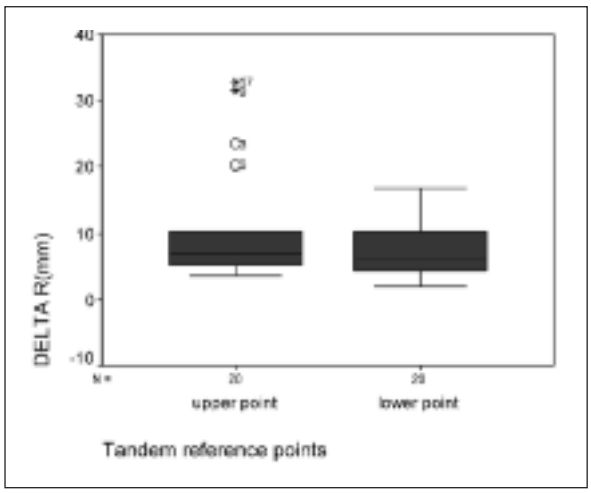


FIGURE 3: Delta R in tandem movements during LDR application.

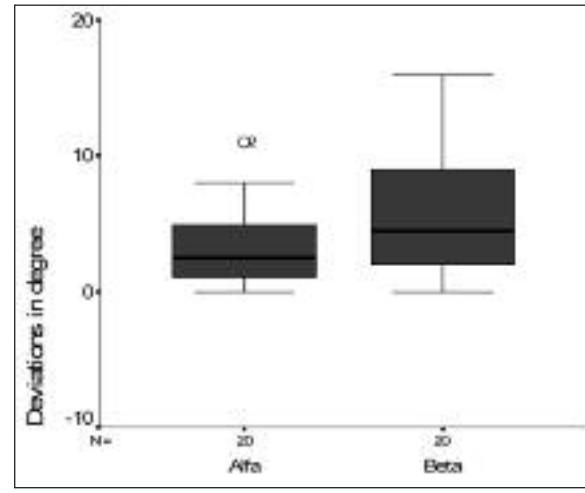


FIGURE 4: Deviations in degrees of tandem movements during LDR application.

TABLE 2: Mean doses in Point A, bladder and rectum between initial planning and recalculation after 24 hours according to the tandem movement for brachytherapy and total treatment.

Reference points		Mean ± SD (n)	Statistical significance (p)*
BRACHYTHERAPY		Dose (Gy)	
Point A			
	Initial	28.82 ± 8.18 (20)	t= 1.01; df= 19;
	24 hours	28.63 ± 8.16 (20)	p=0.59
Bladder			
	Initial	21.08 ± 7.72 (20)	t= 1.55; df= 19;
	24 hours	20.20 ± 7.39 (20)	p= 0.14
Rectum			
	Initial	17.00 ± 5.42 (20)	t= 1.24; df= 19;
	24 hours	15.95 ± 4.72 (20)	p= 0.23
TOTAL TREATMENT			
Point A			
	Initial	81.38 ± 5.73 (18)	t= 1.02; df=17;
	24 hours	81.16 ± 5.43 (18)	p= 0.58
Bladder			
	Initial	72.72 ± 7.73 (18)	t=2.09; df=17;
	24 hours	71.14 ± 8.47 (18)	p= 0.05
Rectum			
	Initial	68.24 ± 5.19 (18)	t=1.96; df=17;
	24 hours	67.07 ± 4.43 (18)	p= 0.25

*: paired t-test.

paracentral dose through the use of intracavitary brachytherapy for optimal local control in all stages of cervical cancer.[3,15] Technically accurate intracavitary applications with proper geometric relationship between tandem and ovoids improved pelvic control compared to the patients treated with unsatisfactory placement.[5] There are several factors that effect the applicator position such as the application procedure, shrinkage of tumor volume and changes in the adjacent organ volumes during brachytherapy. Potish emphasized that experience of the physician was an important issue in optimal applications.[16]

Our study demonstrates that there are some movements of TÖRE's applicator during LDR-BT. The median shift was 6.96 mm (3.61-32.83 mm) for the UPT and 6.36 mm (2.00-16.76 mm) for the LPT. However, radioactive source movement does not result in significant deviations from planned dose over the course of the implants for point A and rectum. Although deviation was statistically significant for the bladder point, the mean dose change ratio was 3.7±3.1%.

Corn et al. found a statistically significant decrease in local control with suboptimal applications compared to optimal applications (34%-68%, respectively; *p=0.02*).[17] Ljunggren et al. evaluated applicator movement in eight randomly selected patients that were treated with LDR remotely controlled Selectron afterloader, and they observed that a significant motion was present (±10^0 in rotation and/or ±8 mm in translation) in 87.5% of the

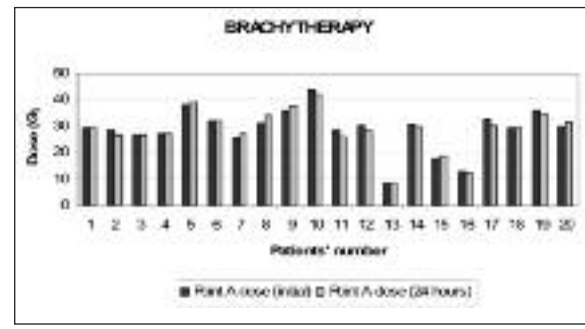


FIGURE 5: Histogram showing the changes in brachytherapy dose from detected applicator movement for reference point A.

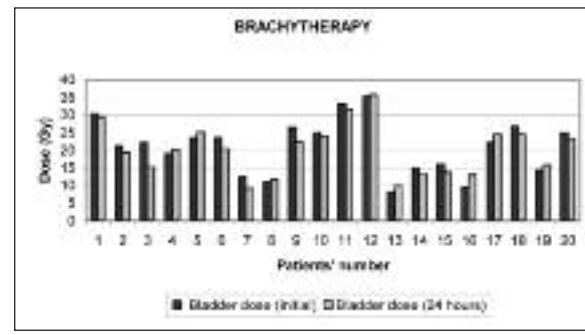


FIGURE 6: Histogram showing the changes in brachytherapy dose from detected applicator movement for bladder reference point.

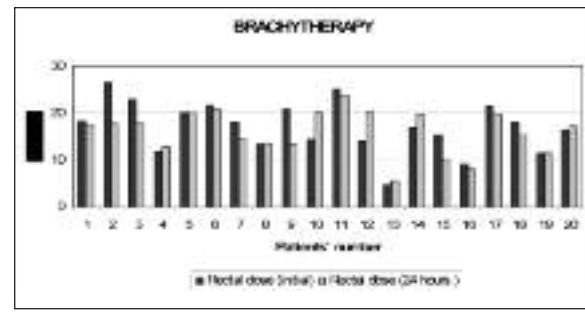
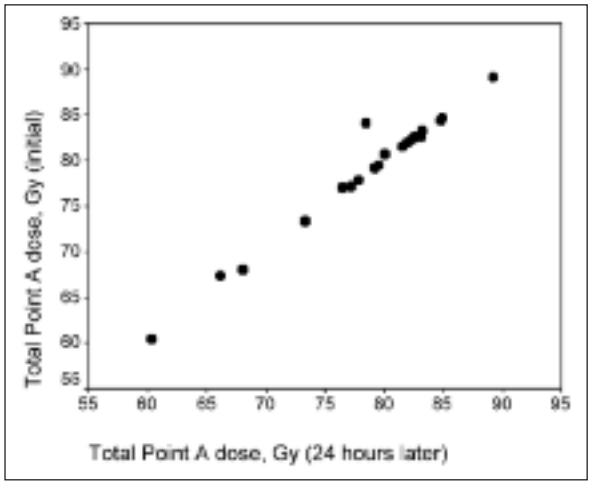
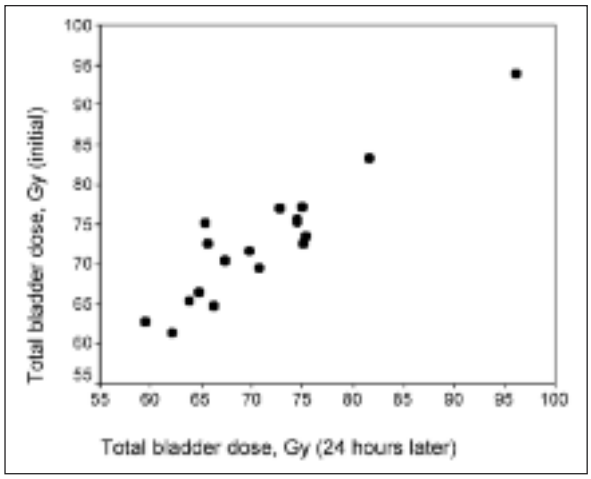


FIGURE 7: Histogram showing the changes in brachytherapy dose from detected applicator movement for rectum reference point.



(Spearman rank correlation), r_s= 0.957, p< 0.001.
FIGURE 8: Initial and recalculated total Point A dose (Gy) correlation.

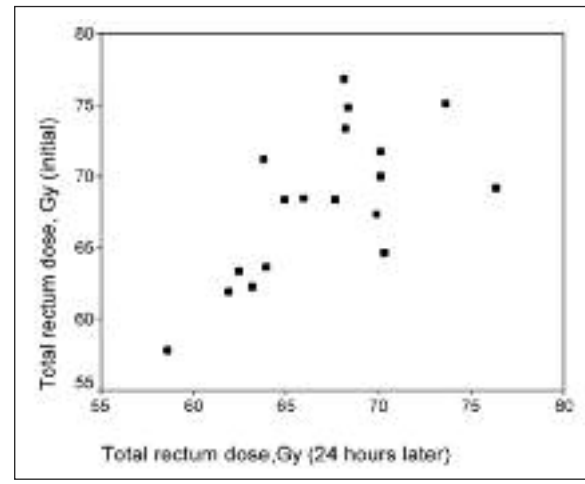


(Spearman rank correlation), r_s= 0.806, p< 0.001.
FIGURE 9: Initial and recalculated total bladder point dose (Gy) correlation.

cases.[18] Grigsby et al. demonstrated 0-26 mm shift of the applicator in the vector analysis.[11] They showed that there was a significant movement in the standard reference points in the time interval between the first and the second LDR brachytherapy. The application resulted in -33% to +19 % change in the dose to point A. This change was due to the tumor shrinkage and fibrosis of normal tissue over time. Thus, they found that the time interval between the implants was the factor which correlates best with the movement in most situations.[2] In our study, the median dose change in the dose point A was 0% (range -4% to +3%). The treatment policy in our institute is to initiate brachytherapy one to two weeks after the completion of external irradiation. Therefore, maximum shrinkage should be performed. This could be the reason for the difference.

Treatment planning results of 25 consecutive patients with cervical carcinoma were reviewed by Elhafany et al.[19] They observed an average displacement of 7.9 mm in each of the point A between high dose rate (HDR) fractions. The shift ranged from 10-13 mm resulted in a dose difference of > 20% for the bladder and rectum points, but less than 8% for the point B. Anatomical changes of the cervix and upper vagina during a course of the treatment resulted a change of volume greater than 10% in 40% of the patients.

In the design of our study, we used the "worse case" model which was mentioned by Corn et al. previously.[20] Although we did not know the exact timing, we considered that the applicator was displaced immediately after the sources were loaded. In spite of this overestimation, the mean dose changes we found were 3.7%, 4.4% and, 1.5% in the bladder, rectum and point A, respectively. In their study, King et al. observed significant applicator movement and deviations from the preplanned point A, bladder and rectum doses over the course of LDR-BT.[12] They were unable to correlate applicator movement with patient age, weight, tumor sta-



(Spearman rank correlation), r_s= 0.622, p= 0.006.
FIGURE 10: Initial and recalculated total rectal point dose (Gy) correlation.

ge, duration and the type of implant or physician performing the procedure. In this study, point A and B correlations were greater than 0.90. On the other hand, the correlations of bladder and rectum maximum and average doses were much weaker, varying from 0.676 to 0.786. They noticed that a small movement in the applicator position could result in large dose variations. In our study, the correlations were 0.96, 0.81, and 0.62 for point A, bladder and rectum, respectively. For point A the correlation was almost perfect whereas in bladder it was weak and in rectum it was weaker. There are unavoidable and uncorrectable motions of bladder and rectum in patients during LDR-BT in addition to applicator movement. Therefore, bladder and rectal dose variations can be demonstrated within the prolonged treatment time.

Katz and Eifel analyzed 808 LDR-BT applications that have been performed in 389 patients.[21] Brachytherapy was administered using a Fletcher-Suit-Delclos tandem and vaginal ovoids or cylinders. The duration of each application was 40-48 hours. They found that the tandem was deviated a median of 0.8 cm (IQ range, 0.4-1.3 cm) from the midline of the patient. They also noted that the applicator was deviated to the involved parametrium in 65% of cases. Although it can be expected much more since the applicator is semiflexible, in our study the deviation of the tandem to the direction of the involved parametrium was similar. Hypothetically, deviation to the involved parametrium can result in higher doses in the regions with high risk. Datta et al. showed a significant variation in the spatial position of point A during the multiple high dose rate brachytherapy (HDR-BT) for either rigid or flexible applicator.[1] The average displacement was 3.8-6 mm for flexible applicator (Ralstron) and 3.5-6.6 mm for rigid applicator (Rotterdam). The mean ΔR for both right point A and left point A was 9.5-10.2 mm, respectively for the flexible applicator and 11.1-10.8 mm for the rigid applicator. Therefore, there was a significant displacement of co-ordinates of point A during multiple HDR-BT procedure, however this was independent of the nature and rigidity of the applicator. On the other hand, in a previous report, the authors reported that the range and the extent of the variability between the 75 applications were significantly more with the flexible Ralston applicator.[22]

In a study on 15 consecutive cervical cancer patients treated by definitive radiotherapy, Corn et al. demonstrated that acceptable geometric relationships and dosimetric outcomes could be maintained throughout LDR procedure.[20] The median displacement which they observed was 3 mm (range 0-9 mm). A 9 mm-displacement was found in only one patient who mobilized during the treatment. The median duration of the insertion was 56.5 hours whereas it was 79.3 hours in our study. One of the disadvantages of LDR-BT is the confinement in the bed during the long treatment time. The machine related rigid applicators can be very uncomfortable and leads to complications due to immobilization. In contrast to machine related afterloading procedure, the patients are free to move with TÖRE's applicator in a protected room, preventing thrombotic phenomena.

Careful selection and placement of the applicators and the sources are the critical issues for a successful intracavitary brachytherapy.[21,23] Positional instability of the applicators is unavoidable either in LDR or in HDR procedure. There are some theoretical advantages of each brachytherapy strategy. Although one of the expected advantages of HDR-BT is the fixed relationship maintained between gynecologic applicator and anatomic structures during the short exposure time, the marked position variations between fractions have been reported.[24-26] The short treatment time of HDR may allow the applicator to remain in a fixed position, but geometric position of the applicator may vary between multiple fractions.The dose variations due to the different geometric position of the applicator indicate treatment planning not only for the first fraction but for every fraction in HDR-BT. Wulf et al. analyzed positional variability of a tandem applicator system in HDR-BT for cervical cancer and they found that there was a considerable variability of the applicator, usually about 20-30 mm with an impact on the prescribed dose to point A of 20-35%.[27] In their study, the impact of tumor stage and increased mobility of the uterus that were due to tumor shrinkage during tre-

atment course did not have a significant effect on the applicator position. However, they pointed that individual anatomic position of the uterus and tissue elasticity that differ among the patients might be related factors. Bahena et al. evaluated the interaction between the geometric variation of the ring and the tandem HDR cervix applicator as well as the impact on treatment results in 18 patients treated with seven fractions.[28] They found the displacement of the applicator with a standard deviation of 6.5 mm in superior- inferior, 5.9 mm in right-left, 7.7 mm in anterior-posterior (AP) direction in 18 patients. The greatest movement was in the AP direction and it was 10 mm in 17% of the applications. They also demonstrated that the applicator position was more stable in the patients with small-volume tumors when compared to those with bulky tumors. Bahena et al. found a correlation between tumor stage and applicator position, in contrary to data from Grigsby et al.[11,28]

In a previous paper, Kim et al. observed that major deviations occurred more commonly in the colpostats than in the tandem, attributed to vaginal packing.[29] Afterwards they compared the frequency of major geometric variations between LDR (50 patients, 100 applications, 2 fractions per patient) and HDR (20 patients, 85 applications, 3-8 fractions per patients) systems in a consequent study.[7] They could not observe major differences in the frequency and types of variation between LDR and HDR applications. The authors pointed that variations in colpostat placements were more common among major geometric variations and they were clinically important than the variations in tandem placement. We found higher movement in the UPT than in the LPT which was fixed with adjoining piece (10.64 ± 8.93 mm v.s 7.47 ± 4.42 mm, respectively). Vaginal packing was not used for the evaluated patients in the current study. Rutten et al. mentioned that vaginal applicators should fit properly within the fornix to minimize the movement.[29] To minimize the probability of overdosage of critical organs or underdosage of target, incorrectly placed intracavitary applicators should repositioned.[30,31] The American Brachytherapy Society (ABS) does not recommend one applicator system over another, except the one which the radiation oncologist is familiar with, to improve the proper brachytherapy application.[32]

Pham et al. evaluated the variation in the applicator position during multiple HDR-BT procedures with an unfixed tandem and ovoid applicator system (HDR Fletcher Suit applicators, Omnitron, Houston, TX).[33] They found that the displacement of the tandem and ovoids were 5 and 4 mm, respectively in the AP direction. The displacements were smaller in lateral and longitudinal directions. This shift resulted in a bladder dose difference of 17.4% between the insertions. Similarly, in our study UPT movement in AP direction was higher than in lateral and longitudinal direction.

The importance of individualized treatment planning has been accepted in external treatment; however this does not apply to intracavitary brachytherapy of carcinoma of the cervix. The use of CT or MRI compatible applicators will allow conformal dose delivery in brachytherapy. The quality of the intracavitary brachytherapy and type of the applicator relevant technical factors have been found to influence the morbidity of radiotherapy in patients treated for carcinoma of the cervix.[34] To improve the therapeutic ratio of the treatment in these patients, the physicians should focus on reducing the complication rates. The determination of critical organ doses with conventional orthogonal film technique may be inadequate. Furthermore, the calculated point doses frequently underestimate the maximum dose to normal tissue or maximum dose to target.[35] CT is an efficient and powerful method in delineating the various organs. CT-based localization allow the correlation of anatomic data with source positioning. Therefore CT planning system for external and intracavitary radiation with dose optimization may cause fewer complications. Therapeutic ratio may be improved with CT- based 3-D treatment planning. However, metal applicators used for the gynecologic implants can produce streaking artifacts that may lead to inaccurate delineation of the critical structures. Allowing high quality CT localization is a potential advantage of TÖRE's applicator, since it is made up of plastic and is CT compatible.

CONCLUSION

In current study, we presented that movement of the semi flexible applicator and dose variations in LDR brachytherapy for cervical carcinoma were acceptable. The limitation of the presented data is that applicator positions are measured from conventional orthogonal films. No data on volumes of the target and critical organs are available. Therefore, studies that are based on more advanced (CT-MRI) imaging are required to achieve further information concerning dose-volume histograms and treatment results in brachytherapy.

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