

Effect of Iridium-192 (Ir 192) HDR Brachytherapy Source Decay during the Treatment Time in Gynecological Intracavitary Brachytherapy Treatment

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ABSTRACT

Background and Aim: In brachytherapy treatment, a small error in the planning gives larger dosimetrical difference in treatment delivery. Basically Iridium-192 decays about 0.5% every 12 hours and 1% per day. Therefore during the treatment time, the source decay would affect the treatment doses. In the commercial available brachytherapy dose calculation planning system the Iridium (Ir192) source decay during the treatment period is not considered. The purpose of this study was to quantify the effect of Iridium (Ir192) source decay during the treatment time in cervical brachytherapy treatment plans.

Materials and Methods: For this study, 48 intracavitary brachytherapy treatment plans are analyzed. The Iridium (Ir192) High Dose Rate (HDR) radioactive source is used for the treatment planning. In every planning, each dwell position time was corrected related to their respective Air kerma strength. The reduction in the Point A doses and bladder and rectum point doses are noted in actual and decay corrected plans in the range of 10 Curie (Ci) to 1.8 Curie (Ci) activity.

Results: It found that maximum 0.23, 0.16 and 0.11 cGy dose differences in Point A, bladder, and rectum, respectively of 1.8 Ci activity plans.

Conclusion: The minimal dose difference in maximum activity plans is due to small dwell position times in plans and the maximum dose difference in minimum activity plans is due to larger dwell position time in the plans. It is concluded that dose differences are not only depending on activity, but also on the position of the point A and bladder and rectum from the lower most dwell position.

Keywords: Brachytherapy, dosimetry, decay, HDR, Iridium-192

INTRODUCTION

In brachytherapy treatment radioactive materials are placed near or within the tumors of the patients. This treatment has more advantages than external beam therapy. Brachytherapy source having greater fall off within a minimum distance gives maximum dose to tumor and minimum doses to surrounding normal tissues. It has an advantage over 3DCRT and IMRT, because of its steep dose gradient between the critical structures and the target.

High dose rate (HDR) brachytherapy in particular has an advantage that the dose can be controlled by altering

the dwell times of different dwell positions.^[1] The accuracy of planning system is important to give maximum dose to tumor and to reduce the doses to organ at risk (OAR).

Present days, remote after loading (operating for longer distance) treatment delivery systems are used for HDR brachytherapy. Iridium 192 (Ir192) high dose rate (more than 12 Gray (Gy) per hour dose) gives greater advantages than low dose rate (LDR), having half life of 73.83 days.^[2] Because of the high rate of the absorbed dose in every treatment fractions and the fact that there less sessions in this brachytherapy treatment compared with teletherapy.^[3] Most commercially available

brachytherapy planning system uses Task Group (TG) 43 formalism for dose calculations, which results inaccuracy in current available planning system dose calculations system.^[4, 5]

The reduction of uncertainties in clinical brachytherapy should result in improved outcome of patients in terms of increased local control of tumors and reduced doses to normal tissue.^[6] Heterogeneity in tissues, bones of the patients and applicators geometry should be included for improving accurate dose calculation formalism.^[7, 8]

The intracavitary brachytherapy has larger dwell position to give pear shape dose distribution with the help of two ovoids and one central tandem. In TG-43 based brachytherapy planning, air kerma strength is considered as source strength. The recommended quantity to specify the strength of gamma emitting brachytherapy sources is either Reference Air Kerma Rate (RAKR) or Air Kerma Strength (AKS).

The vendors should specify the strength of brachytherapy sources in terms of the quantity AKS.^[9] The AKS of the source is used for dose calculation formalism in brachytherapy treatments. Air kerma strength is defined as the product of the air kerma rate, in free space (vacuum) at a measurement distanced from the source centre along the perpendicular bisector and the square of distanced.^[10]

The AKS is continually decreasing with time. But in the planning system, throughout the treatment time it is considered to be of same AKS. The source decays continuously, hence the activity at the end of the treatment is slightly lesser than the activity at the beginning of the treatment. It may cause the dosimetrical error in the brachytherapy treatment delivery.

The present work is carried out to quantify the impact of Iridium (Ir192) brachytherapy source decay during the treatment of intracavitary brachytherapy.

MATERIALS AND METHODS

The Oncentra version 4.5.3 brachytherapy planning system is used in this work. In this study, intracavitary, tandem and ovoids of 48 patient plans were analyzed. Larger tandem length (6 cm) with ovoids of maximum separations (1.5, 2.0 and 2.5 cm) plans consisting of greater dwell position and dwell times plans were selected.

The brachytherapy plans was selected approximately 10 Ci to 1.8 Ci level. Applicators were reconstructed with help of Antero-Posterior (AP) and Right-Lateral (RL) orthogonal X-ray images as recommended by the American Brachytherapy Society.^[11] Prescription Point of Point A in intracavitary brachytherapy plan was created

as per ICRU 38 recommendations as shown in figure 1.^[12] The Point A is commonly used for prescribing doses in gynecological radiation therapy and this point is related to applicator positioning. Dose was prescribed Point A. Point A is described as a point 2 cm up from the cervical OS point of the uterine tube (tandem) and 2 cm lateral to the uterine source, Bladder reference point was created with help of Foleys balloon and rectum reference point created with help of rectal lead wire as per ICRU recommendations as shown in figure 2.^[13]

The plan was generated with well trained brachytherapy planning physicist. In every patient 9 Gy dose is prescribed to Point A and out of 48 patients, for 2 patient plans bladder reference point was not placed due to invisibility in the X-ray images.

The general, two-dimensional, 2D dose-rate equation from the 1995 TG-43 protocol is retained as,

$$D(r, \theta) = S_K \cdot \Lambda \cdot G_L(r, \theta) / G_L(r_0, \theta_0) \cdot g_L(r) \cdot F(r, \theta)$$

Where, $D(r, \theta)$ is dose rate at distance r and angle θ from the source (cGy/h), S_K is Air Kerma Strength of the source in terms of cGy.cm²/h, θ is dose rate constant in water medium in terms of cm². $G_L(r, \theta) / G_L(r_0, \theta_0)$ is geometric factor, $g_L(r)$ is the radial dose function and $F(r, \theta)$ anisotropic function of the source.

The calculation formalism is used to calculate dose rate at point from the radioactive source. Iridium (Ir¹⁹²) HDR brachytherapy source strength measured in terms of Air kerma based formalism.^[14] In every case dwell times are calculated with ratio of dose and dose rate.

Dwell time = Dose / Dose rate

Intracavitary treatment, the source position is determined by applicator design and the treatment planning including the reconstruction of applicator geometry and dwell position and times according to the source strength to deliver the dose to prescribed points.^[15, 16]

Brachytherapy can give the “n” number of dose distributions with help of optimizing dwell time and dwell positions.^[17] The intracavitary unoptimized plans having same dwell time in each dwell positions shown in the figure 3, gives different contribution doses to Point A depending upon their positions.

In the planning system calculations throughout all dwell position time calculation, same air kerma strength is taken. For each dwell position time is calculated by applying corrected AKS with respect to before dwell position time theoretically using standard radioactive decay formula as shown in (Figure 4). Dose of each dwell weight is found. Using weight optimization method, each dwell position dose contribution of Point A is removed

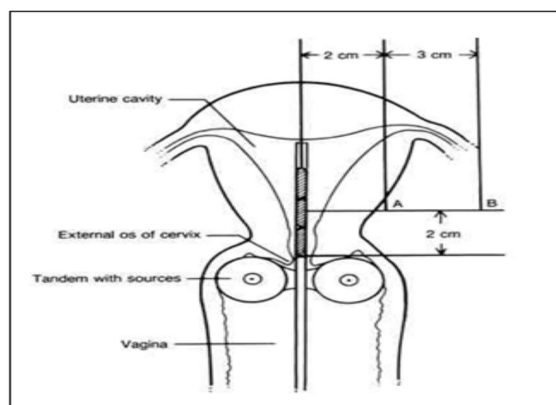


Figure 1 : Point A and B are located per ICRU 38 Recommendation (Source form internet).

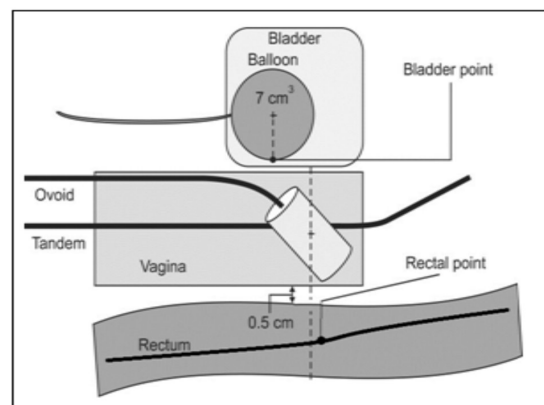


Figure 2 : Bladder and Rectum points are located as per ICRU 38 Recommendation (Source from internet).

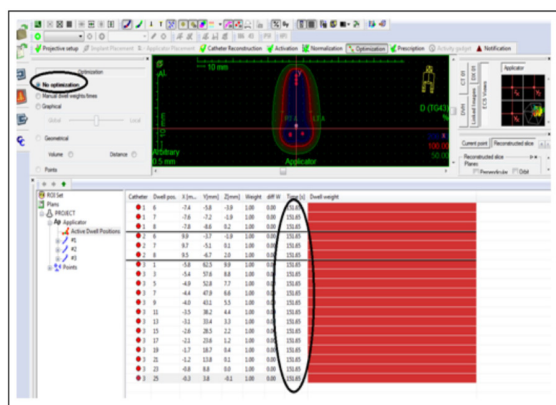


Figure 3 : Intracavitary unoptimized plan having equal weight to every source position.

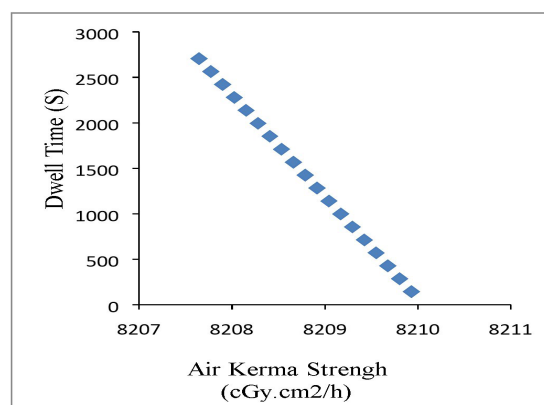


Figure 4 : Variation of Air Kerma Strength of the source with respect to dwell time of the treatment plans.

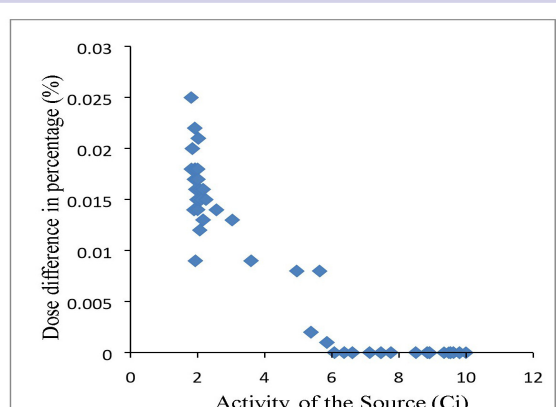


Figure 5 : Percentage difference of prescription Point "A" doses of normal and decay effect corrected plans with different activity.

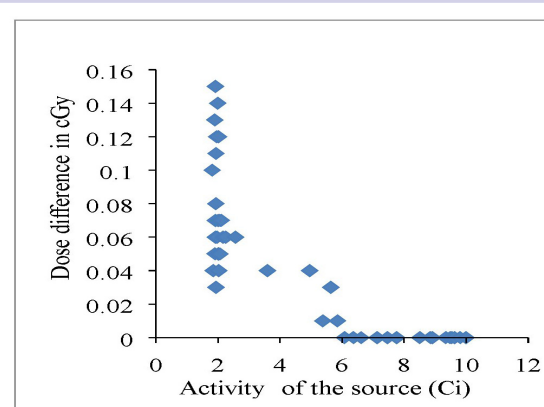


Figure 6: Difference in dose of bladder points of actual and decay corrected plans.

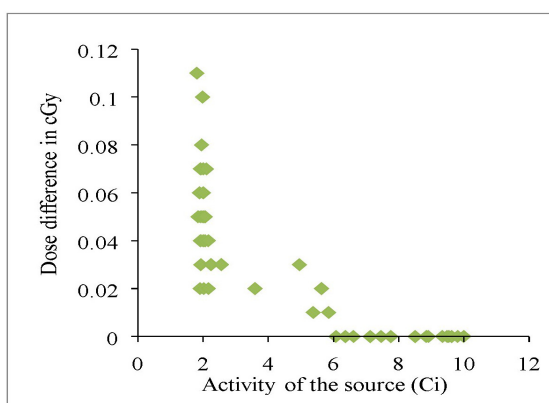


Figure 7 : Difference in dose of rectum points of actual and decay corrected plans.

after making other dwell times zero. The dwell time is calculated theoretically with ratio of dose and dose rate.

The time difference was noted and manually entered with help of manual optimization method in intracavitary copied plans. For each patient, every dwell position is corrected with decay corrected air kerma strength. The reduction in the Point A doses and difference in OAR doses of actual plan and decay corrected plans are analyzed.

RESULTS AND DISCUSSION

In the present study, the effect of decay in iridium 192 (Ir192) brachytherapy source during the treatment time is established. The difference in prescription Point A doses of normal and decay effect corrected plans are shown in the Figure 5. It shows that minimal difference in the Point

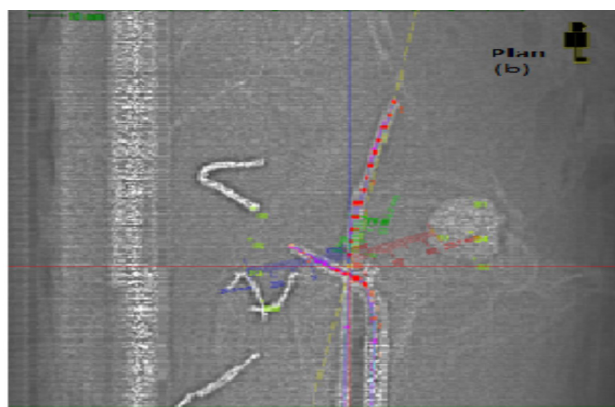
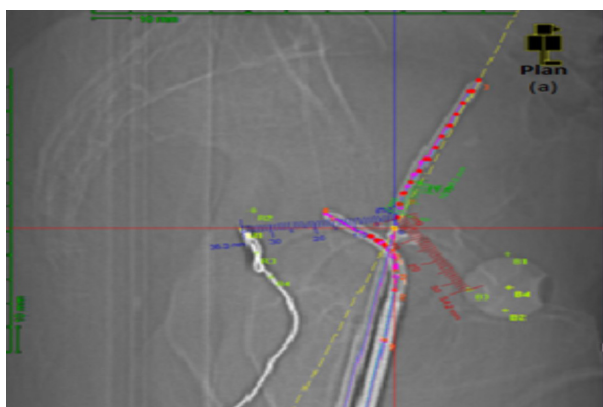


Figure 8 : Plan a shows distance of Bladder, Rectum and Point "A" from a lower dwell position 3.42, 3.63, 1.35 cm respectively and plan b shows distance of Bladder, Rectum and Point "A" from a lower dwell position 2.37, 2.65, 1.42 cm respectively.

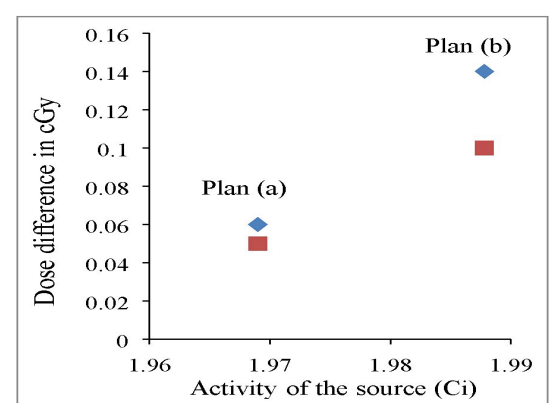


Figure 9 : Plan a shows minimum difference in dose of bladder and rectum due to larger distance from last dwell positions. Plan b shows maximum difference in dose of bladder and rectum due to small distance from last dwell positions.

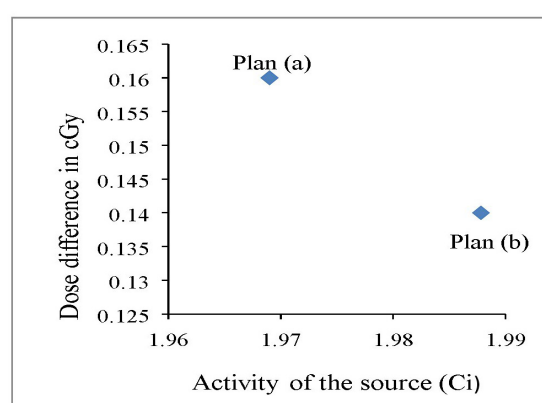


Figure 10 : Plans a and b is planned same activity level and almost same distance to point "A" form the lower most dwell position, 1.3 and 1.4 cm respectively.

A plan done with maximum source activity plans (>5.0 Ci). When the activity decreases, the difference also increases. At the same time, the OAR like bladder and rectum also has certain degree of over estimation in low activity (<5.0 Ci) brachytherapy plans. The over estimation doses to bladder and rectum are shown in figures 6 and 7.

The minimum dose difference is observed between decay corrected and actual plan when activity is more the 5 Ci. Maximum dose difference is observed in bladder and rectum when activity is less than 5 Ci plans. The difference in the doses not only depends on activity but also on applicator position. To show this, two Patients plan A and B were created at same activity level 1.9 Ci but with different distance of bladder, rectum and Point-A from lower dwell position of source as shown in the figure 8.

There is a lot of difference in the bladder and rectal doses with the application done by the different radiation-oncologist, even in the same patient with multiple fractions.^[18] The dose difference also depends on the distance of bladder, rectum and Point A from the last dwell position of the source as shown in the figures 9 and 10. The last dwell position, near the OAR and Point A, affect the dose due to decay effect of the brachytherapy source. Even though difference in doses is minimal at point A, bladder and rectum, there is still difference in the actual doses.

CONCLUSION

The impact of iridium192 (Ir192) HDR brachytherapy source decay during the treatment is calculated. It is found that maximum 0.23, 0.16 and 0.11 cGy dose differences in Point A, bladder, and rectum, respectively of 1.8 Ci activity plans. No dose difference is noted when activity is greater than 5 Ci plans. The difference in the doses not only depends on the activity but also on position of Point A and OAR's from the last dwell position. The dose difference increases with decreasing activity. The obtained effect of decay time on dose is much smaller than typical uncertainty of source strength, and much smaller than other sources of dose uncertainty in the brachytherapy like contouring, planning and realization etc. Even though the dose difference is insignificant in the clinical use, a need to consider treatment time also in decay corrected air kerma strength to improve accuracy in brachytherapy dose calculations.

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CONFLICT OF INTEREST:

The authors declared no conflict of interest.

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