Original Article

The Dosimetric Influence of Central Vaginal Cylinders in High Dose Rate (HDR) Iridium (Ir192) Brachytherapy Treatment

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ABSTRACT

Background: In the brachytherapy treatment plan dose calculations, the effect of applicators densities is neglected. Most commercially available planning systems are using dose calculation algorithm based on TG 43 formalism. In this formalism, whole medium is considered as homogenous water. However in the treatment delivery, applicators are placed inside the patient can cause some dosimetrical changes.

Aim: To determine the dosimetrical influence of central vaginal cylindrical applicators in High Dose Rate (HDR) Iridium (Ir192) brachytherapy treatment using ion chamber and EDR2 radiographic films.

Materials and Methods: In this study the dosimetric influence of central vaginal applicators of different diameters (2, 2.5, 3.0 and 3.5 cm) and plastic catheter (consider as without applicator) were measured from source center to range of distance (2.0 to 6.0 cm) in the water medium. The measurement is carried out in radiation field analyzer (RFA) with help of 0.125 cc ion chamber and EDR2 radiographic films. The experimentally measured doses and treatment planning system (TPS) doses are compared.

Results: The experimental values of plastic catheter measurement data well agreed with TPS calculated data due to homogeneous medium used in the measurement. The difference in the doses is observed when high density applicator is used in a measurement.

Conclusion: Larger differences in doses of 13 cGy were observed when using a small diameter of applicator, measurement at minimum distance from the center of the source, due to scattered photons and secondary electrons produced in the applicator material. For increased distance from the center of the applicators, doses were well agreement with TPS calculated doses due to lesser range of scatter components in the medium.

Keywords: Brachytherapy, dosimetry, EDR2 film, ion chamber, iridium-192

INTRODUCTION

The radioactive material placed near or within the tumor of the patient is called Brachytherapy.[1] The main advantage of brachytherapy is high dose gradient within the small distance gives maximum dose to tumor and minimum dose to nearby normal organs.

HDR remote after loading brachytherapy has been commonly used all over the world.[2] The HDR Iridium-192 (Ir192) brachytherapy gives dose rate of greater than 12 Gray (Gy) per hour having advantage of smaller treatment time.

The single-channel HDR vaginal cuff brachytherapy is used for early stage endometrial cancers in most radiation oncology practice.[3]

The central vaginal applicators are used for cancer treatment of endometrial wall, vagina of cervix or post operative cervix cancer treatments.[4]

It gives cylindrical shape dose distribution to the tumors. The prescription points for central vaginal application are either at surface of the applicator or 0.5 cm distance from the surface of applicators.[5, 6] Difference size of cylinder applicators is used depending upon the size of vagina and patient anatomy.

The most of the brachytherapy treatment planning system use Task Group (TG) 43 based formalism.[7, 8] However, the planning system is not considered for the heterogeneity of patient geometry and applicator densities while calculating the doses.[9] It has considered whole medium like homogenous water.

The high density of the applicators causes dosimetrical error in the treatment delivery. Lack of applicator information in the planning system can cause under dosage or over dosage to the tumor as well as normal tissues of the patients. The HDR vaginal cuff brachytherapy has some significant uncertainties studied by many authors.[10-12]

This study is carried out to quantify the dosimetric influence of inhomogeneity caused by high density central vaginal applicators for HDR Brachytherapy treatment with Iridium 192 (Ir192) source.

MATERIALS AND METHODS

The influence of the central vaginal applicator of Nucletron (Part Number: 084.351, 52, 53, 54) measurements are carried out in water medium using Standard imaging RFA DOSEVIEW 3D. The Iridium 192 HDR source has dimension of 3.5 mm long with a diameter of 0.6 mm.

The source is encapsulated with stainless steel with an outer diameter of 1.1 mm attached with Micro Selectron HDR brachytherapy unit is used for this work. Computed tomography was done for Central vaginal applicator to find the Hounsfield unit and electron density of the material. It is found that cylinder rod having high CT number of 3071 and Electron density of 1.350 is shown in figure 1.

Ion chamber and calibration

The calibration factor is found using plastic catheter having air equivalent density placed on the 2 cm water equivalent slab grooved in 1 cm to keep the ion chamber. Perspex material with near water equivalent density was used for calibration process.[13, 14]

In the Oncentra version 4.5.3 brachytherapy TPS the plan is created with single dwell position of the source giving 1 Gy at 1 cm distance as shown in figure 2. A 0.125 slimline ion chamber used for this measurements and the chamber was coupled to standard imaging max 4000 electrometer. The plan is delivered and ionization charges are measured with help of electrometer mode of cumulative collection. Ion chamber is used to measure the dose in terms of nanocoulomb.[15] The calibration factor is found to convert the ionization charges into absorbed dose in Gy.

The plastic catheter is placed vertically in a RFA and the ion chamber sensitive volume is kept perpendicular to the long of the source.

TPS plan is created with single dwell position of the source planned for 4 Gy, normalized to 1 cm distance and exported to treatment control system (TCS). Measurement is carried out at different distances (2.0 to 6.0 cm) from the center of the source. The applicator diameters of 2.0, 2.5, 3.0 and 3.5 cm are placed into the water medium with help of RFA and same ion chamber is kept at specified distance from the center of the applicator as shown in figure 3(a). Measurement is carried out at different distances (2.0 to 6.0 cm) from the center of the all four applicators.

Usually the cancer cells were located within 0.5 cm for early-stage endometrial cases. The depth prescription deeper than 0.5 cm will deliver larger dose to the vaginal surface due to rapid fall of the radial dose function, results in complications to patients.[16, 17] Thus, study is carried out at 0.5 cm from the surface of the each cylinder applicators. Same distance from the center of the source is measured at TPS. The TPS data is compared with experimental measured doses.

EDR2 radiographic film and calibration

In the current study the ion chamber data are verified with EDR2 radiographic films. The film is calibrated by the iridium 192 source and the source is placed on the water equivalent slab phantom at a particular distance (1 cm) from the film. Basically the EDR2 radiographic films have linear dose response up to 2 Gy for Ir 192 sources [18]. The dimension of film used for calibration is 25.4X30.5 cm2.

In TPS calculation by TG43 protocol for loading the desired dose rate on the film, the dwell time of the source were calculated. The film was calibrated in a range of 2 Gy to 0.01 Gy. After irradiating, the film was developed in the dark room and scanned in EPSON 10000XL and image J software 1.1 is used to calculating optical density by log I0/I formula. The I0 is found from non-irradiated film, developed in the dark room. Calculating their optical density and attributing it to the planned dose, the calibration curve is drawn as shown in figure 4.

The plastic catheter is placed vertically in a RFA and the radiographic film is kept parallel to the along of the source. Same 4 Gy normalized at 1 cm, plan is used for this measurement. Measurement is carried out at different distances (2.0 to 6.0 cm) from the center of the applicators. Different diameter applicators were measured using radiographic films as shown in figure 3(b). The study carried out 0.5 cm from the surface of the all four different diameter applicators. The optical density is found for all

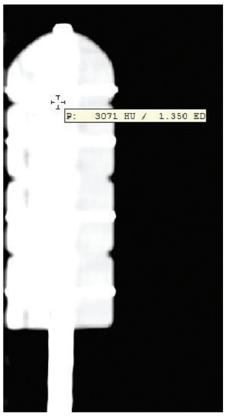


Figure 1: Computed Tomography (CT) image of central vaginal applicator shows high CT number and electron density value.

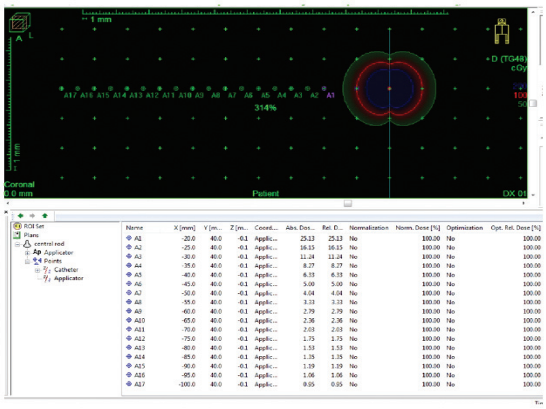
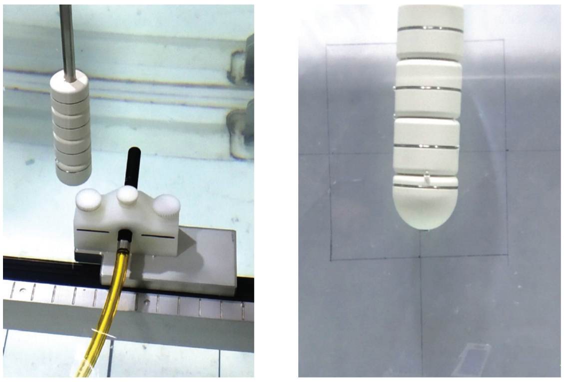


Figure 2: Screen shot of TPS shows calibration plan of ion chamber.



3(a) 3(b)

Figure 3: Central vaginal applicator, doses are measured with 0.125 cc ion chamber 3(a) and EDR2 radiographic film 3(b).

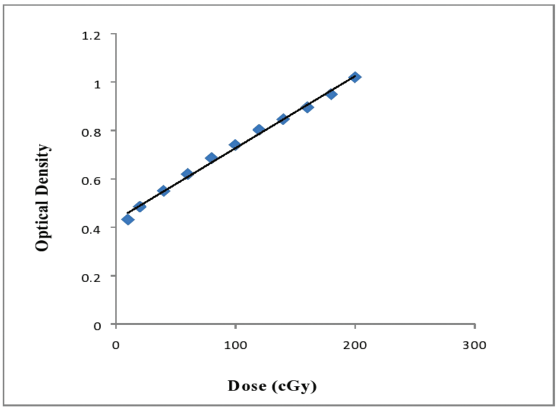


Figure 4: Calibration curve of optical density verses radiation dose using EDR2 radiographic film.

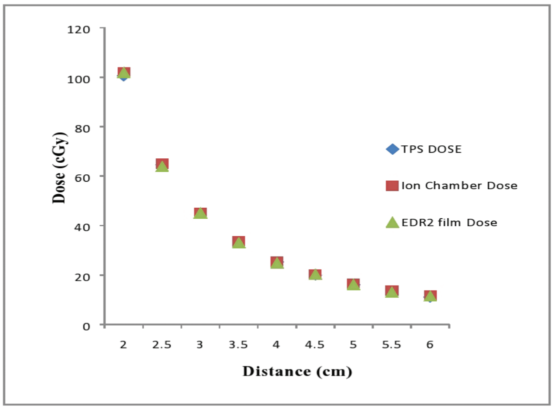


Figure 5: The dose difference between plastic catheter (without applicator) and TPS calculated result shown.

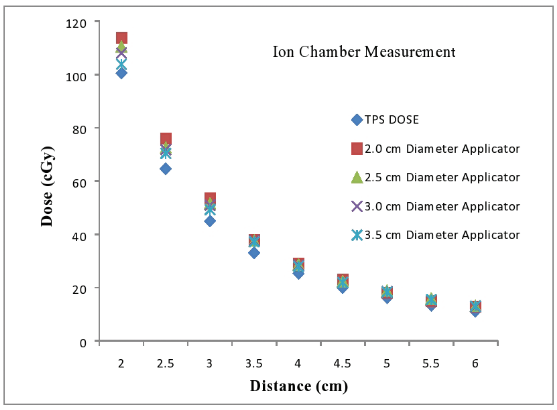


Figure 6: Four different diameter cylindrical applicators doses are measured using ion chamber with respect to various distance from the source and data compared with TPS calculated dose data.

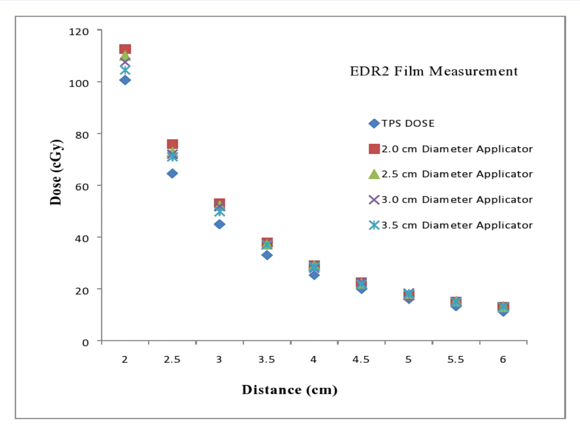


Figure 7: Four different diameter cylindrical applicators doses are measured using EDR2 radiographic film with respect to various distance from the source and data compared with TPS calculated dose data.

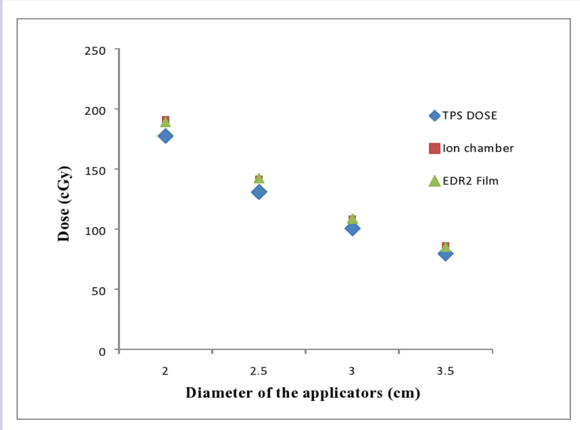


Figure 8: Dose difference of 0.5 cm from the surface of applicators measured with ion chamber and radiographic film and TPS calculated results shown.

irradiated films and dose is calculated using calibration curve.

RESULTS AND DISCUSSION

The influence of metal applicator on the dose distribution during brachytherapy is studied by Chin Hui Wu et al., concluded that the doses calculated from treatment planning system are overestimated by up to a factor of 4 and results suggest that the treatment planning system should take into account corrections for the metal materials applicator in order to improve the accuracy of the radiation dose delivered.[19] In this experiment we tried to establish the relation between the different size cylinder applicators and its dosimetrical influence in the treatment of brachytherapy using ion chamber and EDR2 radiographic films.

The ion chamber data is in well agreement (< 1.2%) with radiographic film data. The ion chamber measurements are repeated thrice to account the setup error. The measured value difference within 1.5 % is observed. The dose difference at different distance from the center of the plastic catheter is measured and it's compared with TPS calculated doses are shown in figure 5. The experimental results are in well agreement with TPS calculated data while measuring with plastic catheter. The result proves that no significant dose difference noted when plastic catheter is used due to very minimal attenuation and less scatter of plastic catheter. So the total medium is considered as the homogeneous water.

The dose is measured for different diameter applicators from center to range of distances. Dose measured at distance in range of 2.0 to 6.0 cm using four different size cylindrical applicators. For all of applicators significant dose difference is found in region of 2.0 to 3.0 cm distance from center of the applicator and the difference is very minimal in the range of 3.0 to 6.0 cm as shown in the figure 6-7.

The high atomic number applicators act as the scatter medium producing the scatter photons and secondary electrons in the water medium. Due to short range of this scatter photons and secondary electrons, near the applicator region maximum dose difference is observed. After certain distance from the applicators the scatter photons and secondary electron losses energy and stopped by medium. So, far no significant dose difference is found when measured at larger distance from the center of applicators.

Compared to TPS, the increase in the doses is noted when measured with 2.0 cm cylinder diameter applicator. This is due to the scatter photons and secondary electrons produced by the applicator travels easily in the applicator having less radius or thickness. When diameter of the applicator increases, decrease in the dose difference is noted, due to some of scatter photons and secondary electrons losses their energy within the applicator material itself. The four applicators dose difference shown with respect to range of distance in figure 6-7.

As per recommendations, the 0.5 cm from the surface of cylinder is the dose prescription point in central vaginal brachytherapy treatments. So each applicator at 0.5 cm from the surface, dose is measured experimentally and the data is compared with same distance from center of source measured in TPS.

The maximum dose difference of 13 cGy is observed in smaller diameter applicator (2.0 cm) and minimum dose difference of 6 cGy is observed in larger diameter applicator (3.5 cm) where measured at 0.5 cm from the surface of the applicators as shown in figure 8. This is due to the attenuation of primary and secondary electrons within the material.

CONCLUSION

The influence of applicators in central vaginal brachytherapy is measured. It is clear that, applicators causing some dosimetrical effect when applicator geometry is not included in the treatment planning. In 2.0 cm diameter cylinder, maximum 13 cGy dose difference is observed.

The larger dose difference is observed when points are measured near the applicators and dose difference is very minimal when points are measured far from the applicators. The use of larger diameter cylinder is decreased dose difference due to self attenuation of some scatter components within the material thickness. However in order to improve the accuracy of dose calculations in the brachytherapy planning system, there is a need to account for applicator hetrogeneity in the plannings.

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CONFLICT OF INTEREST :

The authors declared no conflict of interest.

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