Original Article

An Evaluation of the Effects of Brachytherapy Applicator Attenuation in the High Dose Rate Treatment for Carcinoma Uterine Cervix

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ABSTRACT

Introduction: High dose rate (HDR) brachytherapy using Ir^{192} remote after-loaders has gained acceptance due to the feasibility of outpatient treatment. The aim of the present study was to quantify the difference in dose to a point, due to applicator attenuation in high dose rate intra-cavitary brachytherapy.

Methodology: The applicator (Varian vaginal applicator set central tandem of 6 cm length having an outer diameter of 3.2 mm and a wall thickness of 0.5 mm) was positioned in the wax phantom and the dose at a point (A) was measured using an ion chamber for Ir^{192} high dose rate (HDR) brachytherapy and compared with the treatment planning system (TPS) calculated dose, which does not assume the presence of the applicator. Another experimental setup where the same HDR applicator was positioned at 20 cm from the FC65G Farmer chamber and meter readings were taken for a given treatment time of 100 seconds. The HDR applicator was replaced with a plastic tube and readings were taken for the same treatment time using the same chamber. The measurements were taken with a FC65G chamber with buildup cap for Co^{60} energy.

Results: The average reduction in the measured dose to the calculated dose at point A observed was 2.46%. The average reduction in the measured dose with HDR applicator in place of a plastic tube at 20 cm distance was 3.18%.

Conclusions: Since dose calculations by current treatment planning systems (TPS) are based on the radiation around an encapsulated bare source and do not take applicator attenuation into account, patients receive a lower dose than planned. This suggests corrections for the presence of the applicator may be considered in the planning system to ensure higher accuracy of the radiation dose delivered.

INTRODUCTION

High dose rate (HDR) brachytherapy using Ir^{192} remote after-loaders has gained acceptance due to the feasibility of outpatient treatment. A wide variety of intra-cavitary applicators has been developed for treatment of various anatomical sites. Some applicators are made of metal or other high density materials that have the required strength and permit autoclaving. However, unlike the Cs^{137} which emits 662 keV gamma rays used in the traditional low dose rate (LDR) brachytherapy; Ir^{192} emits a wide spectrum (14885 keV). The low energy components get self-attenuated by the source encapsulation and the effect of attenuation by applicators on patient dose is of concern.

Previous studies have investigated only tungsten and stainless steel shields that are added to Fletcher-Suit gynecological (GYN) applicators to protect the bladder and the rectum.[1] The results showed that such shields reduce doses to these critical structures by 10% to 20%. The attenuation of stainless steel tubes that are an integral part of applicators was reported as 0.5% to 1.0% at distances 0.5 cm from the source and was considered negligible.[2-3] The effect of vaginal plastic cylinders has not been reported in detail. Preliminary studies have shown that such applicators may reduce doses along the transverse plane of the source by up to 3.5%, and even more at oblique angles.[4]

Since dose calculations by current treatment planning systems (TPS) are based on the radiation around an encapsulated bare source, and do not take applicator attenuation into account, patients may receive lower dose than planned.[5-9] The aim of the present study was to quantify the difference in dose to point A, in high dose rate intra-cavitary brachytherapy due to applicator attenuation.

METHODS

The TPS (Brachyvision, Varian Medical Systems) calculated plans are executed and the dose to a point (A) is measured in a custom made phantom using an ion chamber (CC01, 11021, DS05-000, iba Dosimetry). This study does not include any human participant.

Description of source and applicators

The GammaMed Plus HDR brachytherapy machine (Varian Medical Systems) uses a single Ir^{192} source with an active dimension of 3.5 mm length and 0.9 mm diameter in Platinum capsule of 4.5 mm length and 1.1 mm diameter. It has a half-life of 73.83 days. The source is attached to a computerized drive mechanism, which is used to move the source to the predetermined dwell position within the applicator. The applicator, a uterine one, 6 cm long, consists of a 3.2 mm outer diameter stainless steel tube, having a wall thickness of 0.5 mm. The planning system (Eclipse-Brachy vision) run on Windows based operating system and use a digitizer to input source position and the dose calculation points from orthogonal radiographs.

Experimental quantification of difference in dose to point A due to applicator attenuation

The treatment plans were generated for intra-cavitary applications for cervix cancer using orthogonal radiographs by Brachyvision planning system for a prescription dose of 4 Gy to point A. Point A was determined following ICRU 38 recommendations.[10]

Ion-chamber point dose measurements were made in a specially designed and locally fabricated wax and PMMA phantom of dimensions 30×30×30 cm.[3] Wax was chosen as one of the phantom materials because of its local availability, low cost, and ease of machining. Further, it is near tissue equivalent. The phantom is a cube comprising slabs of wax and PMMA. Grooves for positioning the applicator and ion chamber is machined at the center of the wax slab.

The effect of applicator attenuation was assessed by measuring the dose from the HDR Ir^{192} source placed in a commonly used intrauterine tube (Varian vaginal applicator set central tandem of 6 cm length having an outer diameter of 3.2 mm and a wall thickness of 0.5 mm). For this purpose, the applicator was positioned in the wax phantom, and the dose at point A was measured using ion chamber. The dose was calculated using the TPS also, which does not assume the presence of the applicator, and the results were compared with the corresponding values of the dose measured using ion chamber.

Steps in Dose calculation

$D = M \times CF \times K_{TP} \times K_{pol} \times K_s$

where

M = Meter Reading

CF= Calibration Factor for the chamber used

$N_{DW} = 3.127 \times 10^9$ Gy/ C

Beam Quality Co^{60}

K_{TP}=Temperature Pressure Correction Factor

$K_{TP} = 1.14$

K_{pol}= Polarity Correction Factor

$K_{pol} = 1.00773$

K_s= Saturation Correction Factor

$K_s = (V_1/V_2)^2 - 1 / (V_1/V_2)^2 - (M_1/M_2) = 0.99445$

Another experimental setup was arranged to quantify the applicator attenuation. The same HDR applicator was positioned at 20 cm from the FC65G Farmer chamber and meter readings were taken for a given treatment time of 100 seconds. The HDR applicator was replaced with a plastic tube and readings were taken for the same treatment time using the same chamber. The measurements were taken with FC65G chamber with buildup cap for Co^{60} energy.

RESULTS

The average difference (reduction) in the measured dose to the calculated dose at point A was found to be 2.4573%. Since dose calculations by treatment planning system (Brachyvision) are based on the radiation around an encapsulated bare source, and do not take the presence of applicator into account, patients receive less dose than planned and in the present study the average percentage reduction was about 2.46.

The average difference (reduction) in the measured dose with HDR applicator to the measured dose with plastic tube at 20 cm distance is found to be 3.18%. So the average percentage reduction in dose due to the presence of HDR applicator is 3.18.

DISCUSSION

The dose calculation algorithm of the Brachyvision planning system is based on the recommendations of the AAPM Task Group 43.[11]

The dose rate, D (r, θ) at point (r, θ) where r is the distance to the point of interest and θ is the angle with respect to the long axis of the source can be written as

$$D(r,\theta) = S_k \Lambda [G(r,\theta)/G(r_0,\theta_0)] g(r) F(r,\theta),$$

where

S_k = air kerma strength of the source

Λ = dose rate constant in units of cGy/ h/U)

where 1U = 1c Gy cm^2/h

G(r, θ) = geometry factor

g(r)= radial dose function

F(r, θ) = anisotropy function

The AAPM TG-43 formalism describes 2D dose distributions in water-equivalent homogeneous media for a cylindrically symmetric radioactive source. Provided that cylindrical symmetry is maintained, the general form of the TG-43 formalism can be extended to include source-applicator systems. Strict adherence to the AAPM TG-43 protocol for an applicator would require calibration of the source-applicator system by the National Institute of Standards and Technology (NIST) or any other approved calibration laboratories to obtain the air-kerma strength of the assembly. One would then have to compute the dose rate constant and, finally, the radial and anisotropy functions of the system. Such a procedure would be expensive and impractical.

In this study, the centroid of sensitive volume of the chamber was positioned at point A with respect to the HDR central tandem applicator and measurements were carried out executing the brachy vision calculated plans. The dose to point A was calculated. Correction factors for tempera- ture, pressure, polarity, and recombination were applied. The difference in dose to point A in the experimental setup with brachyvision plan was estimated. The experimental arrangement is shown in figure 1 and the experimental arrangement to quantify the applicator attenuation is shown in figure 2.

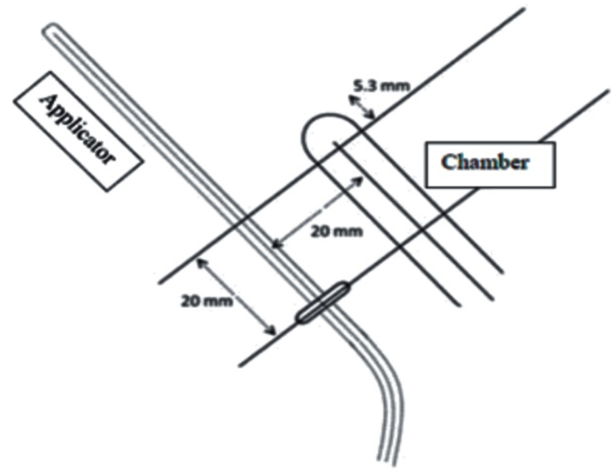

Figure 1: Experimental arrangement of the HDR applicator and chamber in the phantom.

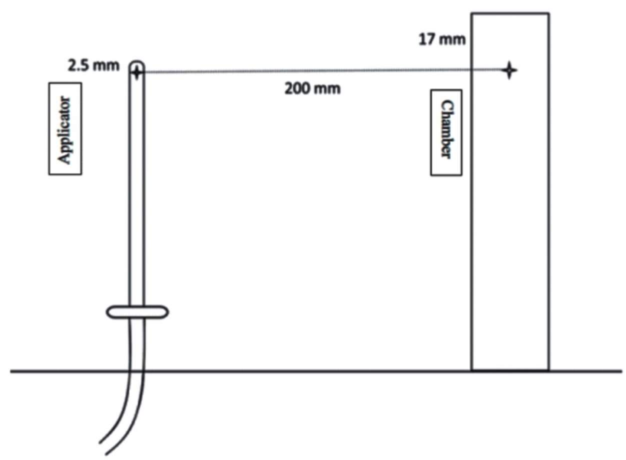

Figure 2: Experimental arrangement of the HDR applicator and chamber in air equivalent phantom.

Ye et al[2,4] reported an overestimation of 3.5% in the calculated dose and they have used 0.125 cm^3 ion chambers. Wu et al[5] also reported an over estimation by up to a factor of 4 by the treatment planning system. They have used 0.01 cm^3 pinpoint ionization chamber for the measurements. Their results are very much in agreement with the findings of the present study. Uniyal et al[6] measured the applicator attenuation by EBT2 film for a commonly used stainless steel uterine tube in a homogeneous water equivalent phantom and compared the measured doses with the TPS calculated values. The attenuation due to applicator presence compared to TPS calculated dose quantified was 2%.

CONCLUSION

This study explored the effect of applicator attenuation while treating carcinoma uterine cervix with brachytherapy. The treatment planning system, which currently does not take into account the presence of applicator, overestimates the dose. Corrections for the presence of the applicator may be considered in the planning system to ensure higher accuracy of the dose delivered.

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