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Comparison of Planned and In-Vivo Measured Rectal Dose during Intracavitory Hdr Co^{60} Brachytherapy in Cervical Cancer

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Abstract

Background: The use of Co-60 as source for HDR brachytherapy poses a question on whether the rectum will receive higher radiation dose due to the relatively higher average gamma energy of 1.25 MeV. In vivo dosimetry, where dosimeters are placed in or on the patient, is one way of verifying the dose.purpose of this study to measure rectal dose during treatment and compare between calculated by tps and measured by Diode.

Material and method: 50 patients of carcinoma cervix were included in this study during last two years. Intracavitary brachytherapy FLETCHER SUIT applicator was inserted.An amorphous silicon diode which encapsulated with rubber was inserted into rectum. Relation between diode and rectal wall was explained very well .Images which obtained by C-arm transferd to treatment planning system which calculated rectal dose. After treatment dose measured by diode and calculated by TPS were compared.

Results: Mean dose as per TPS and Diode Calculation 4.43Gy and 4.56 Gy respectively. 95% Confidence interval limit for TPS 4.43 +/- 3 and for diode is 4.56 +/- 3.32. As observed from table the dose measured using diode is higher than that by TPS , but it is not statistically significant($P<0.69$) as per Mann –Whitney U test. There was a observable difference between both doses but it was not significant.

Conclusion: Hence it can be summarized from our study that there is a difference between the TPS and the in vivo dosimetry ,but this difference is not statistically significant(p value >.05). In vivodosimetry is beneficial for an individual patient.

Keyword: invivo dosimetry, cervix, diode, brachytherapy

Introduction

In general, Radiation therapy is the standard mode of treatment for most of cervical cancer. When intracavitory HDR brachytherapy combined with EBRT, it potentiates the efficacy of treatment modality. Now a days Co-60 is replacing Ir-192 in most of institute due to its long half life (5.26year)[1].The half life of Ir-192 is 74 days which is much smaller than co-60 needing frequent change in the source so Co-60 brachytherapy is more cost effective as compared to Ir-192 due to this advantage Co-60 gained in popularity as HDR brachytherapy source[2].

Co-60 showed comparable result to that of Ir-192 regarding qualitative isodose distribution, anisotropy and radial dose function. The main difficulty in giving the planned radiation dose to the tumor during cervical brachytherapy is the possibility of radiation toxicity to normal organ at risk, specially the rectum[3].

Optimization algorithm delivers maximum dose to the tumor and minimum dose to rectum but in some situation as like anatomical variation or some unidentified unknown factors,rectum receives unacceptably higher dose.Co-60 has 1.25 Mev average gamma energy and Ir-192 has 0.38 Mev, the probability of rectum receiving higher dose increases when Co-60 is used as a source of brachytherapy. Park et al.[4] compared reference point doses; Co-60

and Ir-192 for HDR brachytherapy and reported that rectal doses were 0.8% higher than Ir-192. Palmer et al[5]. reported that plans generated using Co-60 delivered up to 10% greater dose within the rectum along the extension of the applicator axes and lower doses to regions more distant from the applicators compared to plans generated using Ir-192 due to this increased probability of rectal dose, brachytherapy should be closely monitored.

In HDR brachytherapy high dose is used in short period of time, so it becomes necessary to enhance our verification system or monitoring system that can keep accurate check on the rectal dose between measured and calculated dose.

In Vivo Dosimetry can be a option for dose delivery accuracy measurement during treatment[6].In vivo Dosimetry recently potentiates the brachytherapy by safe guarding the normal tissues, specially the rectum. By using IVD, treatment can be interrupted at any point of time during treatment,to avoid misadministration of the dose discrepency between measured and calculated dose.

HDR and LDR brachytherapy IVD methods are diodes, TLD, plastic scintillation detector[7][8] .

Though IVD is still a developing tool of verification of treatment delivery system, its implementation and application has some difficulties. The design of dosimeter must be limited to insert into rectum, catheters and applicators .The major difficulty in using IVD is to determine the exact location of placement of dosimeter ,in high dose gradient fields. In addition,stem effect ,angular response anisotropy, volume averaging, and energy dependence are possible restrictions that might cause measurement uncertainty to be excessively high, further limiting the practical usefulness of IVD detectors[9].

Material and Method

The present study was carried out in 50 patients, histopathologically confirmed newly diagnosed cases of Squamous cell carcinoma of cervix stages II and III, and registered for treatment our department.

Brachytherapy

After EBRT, intracavitory brachytherepy given by miniature source Co60 of dimension 3.5mm× 0.5 mm of strength 1.95 ci.

Brachytherapy schedule

22.5gy in 3 fractions, 7.5gy per fraction, each fraction 3 days apart.

Procedure

Intracavitary application was done under intravenous sedation in Mini-operation theater. Before Intracavitary application, bladder and bowel were emptied by catheterization and pc enema respectively. The catheter bulb was filled with 7^{ml} fluid (5^{ml} Normal saline and 2^{ml} Iohexol dye) for urinary bladder dosimetry.

After assessing uterine cervical length with uterine sound, appropriate intracavitary brachytherapy FLETCHER SUIT applicator was inserted. Finally vaginal packing (beta dine socked) was done to displace

the rectum and bladder away from the intracavitary applicator, and to immobilize the applicator.

For rectal dosimetry a lead marker fix with a sterile stick by adhesive t was placed along the posterior vaginal wall, rectal point situated about 5mm behind the posterior vaginal wall. Rectal point marked as R1,R2,R3.uppermost point marked as R1 and rest points situated 1cm downward from each other. Treatment planning was done by using C-arm X- ray machine, X-ray pelvis both AP and Lateral view was taken for planning of intracavitary brachytherapy.

During the brachytherapy procedures, a C Arm compatible brachytherapy applicator (Fletcher suit) set consisting of two ovoids and an intrauterine tube (tandem) was used for securing the Co-60 source during irradiation. During each insertion, the intrauterine tube was placed into the uterine cavity and the ovoids were positioned in the vagina at the level of the fornices. The rectal diode (encapsulated with rubber) was then inserted into the rectum of patient with taking consent and affixed to the patient's body with an adhesive band.

Following applicator and rectal diode insertion, C Arm images of patient was obtained. Image data set was then transferred to the HDRplus™ TPS via DICOM network for treatment planning.

Relation between rectal wall and rectal diodes:

The rectum, the rectal Diode and the applicator could be defined accurately on C-ARM images. The diode received maximum dose during treatment and positioned almost at the level of the ICRU rectal reference point R1 (It is the nearest point from source at Rectal marker), which also coincided with the region of highest dose in the rectum. The Diode was in close contact with the inner anterior rectal wall. Our Rectal reference point also coincided at Diode, if mismatch then we corrected the Diode position through fluroscopy.

Our physicists were used series of image and generate plans and they defined bladder and rectal point according to ICRU reference point. In addition, diode was identified on the images. Appropriate source positions and diode position were determined with sufficient dwell time for each applicator tube. Plans were approved by the oncologists and plan data was sent to MultiSource® control console for delivery of treatment. Diode measured doses compared with calculated TPS doses.

We used Bebig MultiSource 20 channel® HDR brachytherapy treatment unit model in this clinical study. The radiation source used in Bebig Co-60 model is Co60.A86 stepping source. The source strength (reference air kerma strength) is provided on the manufacturer's source certificate.

The Co-60 source has an active core of 0.5mmin diameter and a central cylindrical active core length of 3.5mm.An amorphous silicon diode was used for rectal dose measurement. This semiconductor diode surrounded by a rubber encapsulation. It had a diameter of 5mm and 8cm length. This diode was connected to a Multidose electrometer via a single pin channel of the treatment unit. Prior to every in-vivo rectal dose measurement, the diode was calibrated with the Co-60 source and electrometer. The aim of diode calibration was to obtain calibration factor for diode, which was used to calculate the absorbed dose during in-vivo dose measurement. To achieve this, charge was collected by the diode at a known present time during Co-60 irradiation then it was converted in absorbed dose.

Calibration factor for diode was calculated . After then rectal doses by TPS and In Vivo rectal diode were compared.

Results

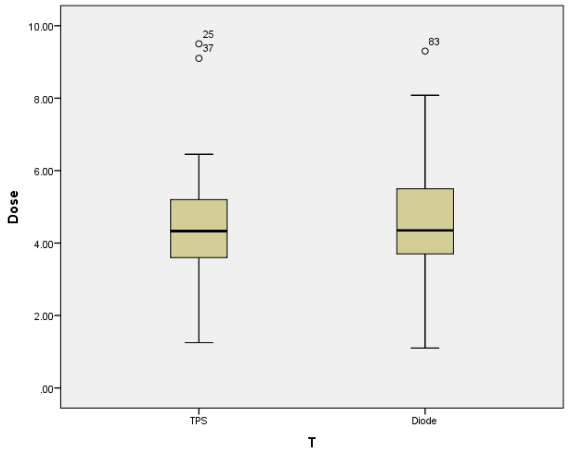

Figure 1: plot box between calculated dose by TPS and measured dose by diode.

Median difference is identified by the dark line inside the box, upper and lower bars represent maximum and minimum value, the circles represent the outliers (>1.5 interquartile range and <3 interquartile range from height of box).

As seen from the plot there is minimal difference between the median value but there is a observable difference in the range between the two modalities

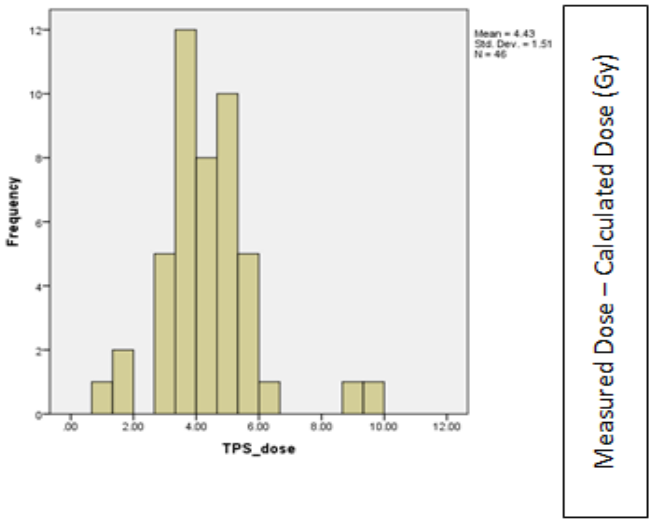

Figure 2- chart plot depicting the frequency distribution between rectal dose received(x-axis) and no of patients(y-axis) as per TPS calculation.

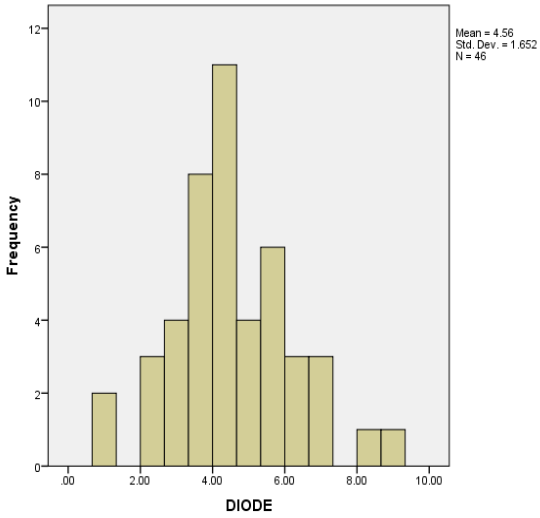

Figure 3- chart plot depicting the frequency distribution between rectal dose received(x-axis) and no of patients(y-axis) as per Diode measurement.

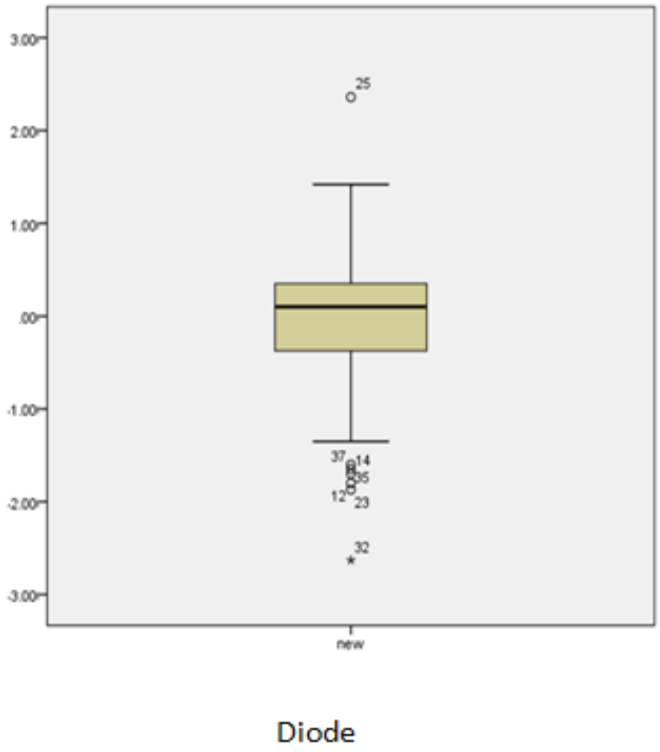

Figure 4.This is a box plot of differnce between calculated dose by TPS and measured dose by diode .Median difference is identified by the dark line inside the box , upper and lower bars represent maximum and minimum value, the circles represent the outliers(>1.5 interquartile range and <3 interquartile range from height of box).*represents extreme outliers ≥ 3 interquartile range

Modality	N	Mean(Gy)	Std. Deviation	P value
TPS	50	4.4311	1.50967	0.69
Diode	50	4.5613	1.65239	

Table 1.table showing the mean dose as per TPS and Diode Calculation 4.43Gy and 4.56 Gy respectively. 95% Confidence interval limit for TPS 4.43 +/- 3 and for diode is 4.56 +/- 3.32. As observed from table the dose measured using diode is higher than that by TPS, but it is not statistically significant(P<0.69) as per Mann – Whitney U test.

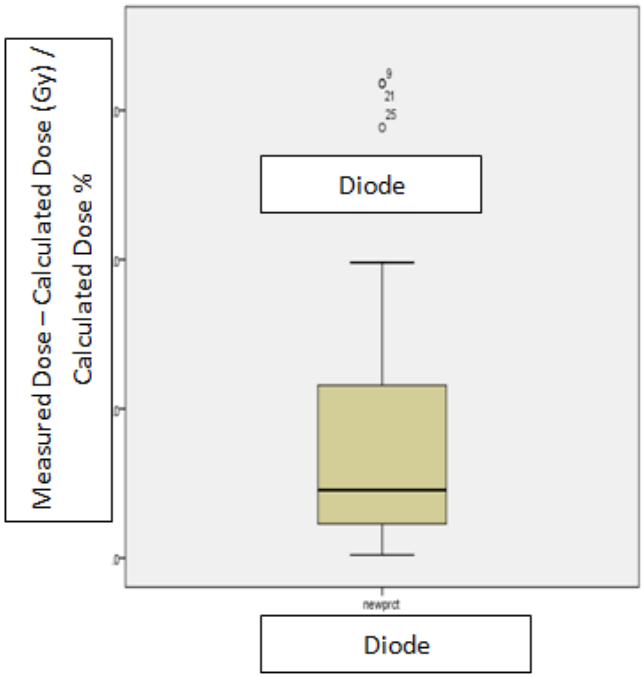

Figure 5.This is a box plot of percentage difference between calculated dose by TPS and measured dose by diode .Median difference is identified by the dark line inside the box , upper and lower bars represent maximum and minimum value, the circles represent the outliers (>1.5 interquartile range and <3 interquartile range from height of box), Box plot showing difference and percentage difference between measured and calculated dose in 50 brachytherapy application, the absolute percentage difference between calculated and measured dose range from 15 to 38%. This corresponds to dose difference ranging from 0.1 Gy to 2.6Gy, According to this box plot median percentage difference is only 0.4 Gy (9%).

Discussion

The only practical and feasible method to asses the actual dose delivered during external beam radiotherapy and brachytherapy is IVD[10] . IVD measures the discrepences or errors in the doses calculated by TPS and actual dose delivered. IVD can be done by many methods. Minor changes of distance between axis of uterus and rectum can result in major changes of rectal dose because of high dose gradient region in this direction. Lateral and longitudinal movement almost along isodose curve so they do not produce major rectal dose variations,while anterior –posterior movement of Diode and Applicator could produce major deviation due to high dose gradient region[11]

In our study we used silicon semiconductor based diode ,measurement or characterstics of different types of semiconductor diode are documented in literature[12].

We perform weekly calibration of our diode which is sufficient for clinical use, so there is no need of daily calibration balatals et al[13] .

Percentage difference between calculated and measured rectal dose in this study were in the range of 5% to 38% (median ¼ 2.2%). When we compared with In vivo rectal dose measurement using Ir-192, percentage difference in our study were large but comparable. Waldh€ausl et al[14]. reported percentage dose differences of _31% to 90%

(mean ¼ 11%) between calculated and measured dose during HDR brachytherapy using Ir- 192. In a similar study, Eich et al[15]. reported differences of _50% to 40% (mean ¼ 4 ± 19%) between calculated and measured doses using diodes.

Dose deviation between planned and actual dose were recorded at R1 reference point. Our R1 reference point was more prone to geometrical shift between treatment delivery .Rectal peristalsis and patient movement can also affect IVD. Diode displacement is very important source of error which is published in many studies. phantom studies performed by Niroomand-Rad et al[16]. 1987 showed uncertainties in position of 0.3 mm and Kolkman-Deurloo et al[17]. 1997 found uncertainties of up to 0.24 mm

To minimize the dose discrepancies or varation due to geometrical shift, diode position was determined pretreatment and post-treatment by using C-arm fluoroscopy . This was supported by Allahverdi et al[10]. which confirmed that the diode displacement was the reason for the over response of the diode.

We used stainless steal metal applicator in our study .some studies state the dose attenuation upto 2% along transverse plane of the source when metal applicator used. Our TPS does not consider this factor in its algorithm .

The absolute difference was small as median difference of 2.2% was reported in our study corresponding 0.3gy which is only 04% of the prescribed dose, although data of percentage difference were significantly large

Although the values of percentage difference were considerably large, the absolute difference was reasonably small where median difference of 2.2% recorded in this study corresponded to 0.3 Gy, which is only 04% of the prescribed dose of 7.5 Gy. The results from our study also revealed that a large proportion of the differences was attributed to higher calculated doses by the TPS Hence it can be summarized from our study that there is a difference between the TPS and the in vivo dosimetry ,but this difference is not statistically significant(p value >.05). This study thus stresses the role of invivo dosimetry to measure the absolute delivered dose which can vary from the TPS measured dose due to factors like patient movement, applicator displacement and various other unaccounted factors. Hence accidental delivery of large doses can be scrutinized and corrective measures can be undertaken in the remaining fractions of therapy. In vivo dosimetry is beneficial for an individual patient.

Conclusion

In gynaecological brachytherapy it is recognised that in-vivo dosimetry provides information that contributes to reduce the risk of large errors in dose delivery. When calibrated and used in appropriate conditions, diodes provide results that are sufficiently accurate and reproducible for clinical applications.

In this study there was a observable difference(5 to 38%) between calculated dose by TPS and measured by rectal diode but minimal difference between mean and median doses.when we concluded statistically significance,it was insignificant (p value >0.05).TPS calculation can be used for rectal dosimetry but at individual patient level In vivo dosimetry can be measured interfraction variations, variations between planning and actual treatment delivery.

This study favors the feasibility of IVD to estimate the rectal dose during HDR brachytherapy using Co-60.The probability of uncertainty are similar in both Ir-192 and Co-60.The most significant being the chance of positional shift in between application and treatment. Despite these uncertainties ,IVD is helpful for physicist and other staff which provide great level of confidence to them on the accuracy of treatment. It is therefore recommended for treating institutions to have their own invivo dosimetry

program of quality assurance to ensure safe HDR brachytherapy delivery.

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