MAK HILL Publications Research Journal of Medical Sciences

Research Article
doi: 10.59218/makrjms.2023.684.689

# Analysis of Dosimetric Differences between Two High Dose Rate Brachytherapy Sources in Intracavitary Applications: An Institutional Experience

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**Key Words**
Sagiplan, brachyvision, Ir-192, Co-60, treatment planning

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**Received:** 6 July 2023
**Accepted:** 1 August 2023
**Published:** 3 August 2023

**Citation:** N. Shashikala, B. Shwetha, B. Rekha Reddy, S. Sathiyan and K.M. Ganesh, 2023. Analysis of Dosimetric Differences between Two High Dose Rate Brachytherapy Sources in Intracavitary Applications: An Institutional Experience. Res. J. Med. Sci., 17: 684-689, doi: 10.59218/makrjms.2023.684.689



**ABSTRACT**
This study aimed to compare and evaluate the intracavitary treatment plans performed using two different treatment planning systems one incorporating Ir-192 source and the other Co-60 source. 50 computed tomography (CT) based intracavitary brachytherapy treatments, planned in SagiPlan and BrachyVision treatment planning systems were analyzed. For each patient planned in Sagiplan, a comparative plan was generated in BrachyVision maintaining the same dwell positions and dose to point A. The treatment plans were compared based on the clinical parameters such as $D_{90}$, $D_{50}$ for HRCTV and dose to 0.1 cc, 1 cc and 2 cc of OARs namely bladder, rectum and sigmoid. Percentage difference of 1.95 and -0.79% was seen in the $D_{90}$ and $D_{50}$ values of HRCTV between Ir-192 and Co-60 radioisotopes. Statistically significant differences of 9.43, 8.02 and 9.0% was observed respectively in the 0.1 cc, 1 cc and 2 cc volumes of sigmoid. Also mean percentage difference of 0.95, 3.0 and 5.31% was seen in $D_{0.1cc}$, $D_{1cc}$ and $D_{2cc}$ of rectum. Further $D_{0.1cc}$, $D_{1cc}$ and $D_{2cc}$ values of bladder were -3.04, -2.12 and 2.4%, respectively. No significant difference was observed in the volumes encompassed by 50, 100, 150 and 200% isodose volumes between the two radioisotopes. The treatment time was approximately 1.2 times higher with Co-60 as compared to Ir-192. The dosimetric parameters analyzed for Co-60 and Ir-192 sources showed comparable results. Significant differences between the two sources were observed in the doses to sigmoid which could be due to the bulge in the isodose lines of Co-60 source along the longitudinal axis. These differences could be eliminated with appropriate techniques of optimization in the actual treatment plan.

## INTRODUCTION

Brachytherapy (BT) is an important tool for both definitive and adjuvant treatment of cervical and endometrial cancers. Brachytherapy allows delivery of high radiation doses to the tumour with rapid fall-off to spare the surrounding normal structures. The definitive treatment for patients with locally advanced cervical cancer involves external beam radiotherapy (EBRT) and concurrent chemotherapy followed by a BT boost to achieve optimal treatment outcomes[1]. Brachytherapy is necessary to deliver a highly effective dose to the primary tumour. The ability to safely deliver a high dose to central disease undoubtedly explains the excellent local control rates that can be achieved when cervical cancers are treated with a combination of EBRT and BT[2].

Over the past three decades, the use of high dose-rate BT (HDR BT) has substantially increased over low dose-rate BT (LDR BT) internationally. Several studies have reported that there are no differences between LDR and HDR brachytherapy in terms of overall survival, local recurrence and late complications[3-5]. Nevertheless, with HDR BT, there is significant variation of the total tumour dose, the dose delivered per fraction and the proportion of tumour dose delivered with EBRT versus BT[6]. Advantages of HDR BT include opportunities for outpatient treatment, avoidance of exposure to staff from the radiation source, consistent and reproducible applicator positioning and dose optimization attained with a variable dwell-time stepping source[6].

In HDR BT of cervical cancer dose can be delivered with a traditional intracavitary approach (IC alone) or with multiple needles or interstitial approach (IS) in order to optimize the dose distribution. The components of intracavitary BT (ICBT) include an intrauterine applicator like tandem which is used in conjunction with intravaginal components such as vaginal ovoids or a vaginal ring. Varieties of tandem lengths and curvatures, as well as different ovoid diameters are available and are selected based on patient anatomy. A study by Kallis *et al*.[7] using knowledge-based intracavitary models and clinical data suggested that significant OAR sparing can be achieved with tandem and ring over tandem and ovoid applicators, particularly for the rectum.

The availability of smaller sized sources allowed interstitial treatment with needles and catheters and aided better optimization of dose. The production of small sources for HDR afterloading was only possible for 192-Ir, because of technological reasons. This made 192-Ir the most widely accepted radioisotope for HDR afterloading brachytherapy worldwide. Recently, Co-60 radioisotope has been gaining popularity due to economic and logistical reasons compared with the traditional Ir-192. Currently Co-60 sources are available with identical geometrical dimensions as miniaturized Ir-192 sources. Several studies have demonstrated the equivalence of Co-60 and Ir-192 sources with respect to physical data, source construction and dose distribution of a single source[8-13].

Though differences exist in the physical characteristics of the two sources Co-60 provides economic and logistic benefits over Ir-192. Owing to the longer half-life of Co-60 (5.26 years), typical source replacements would be only once during which there would be 25 exchanges of Ir-192 source (half-life of 74 days).

This study aimed to compare the dosimetric parameters of ICBT treatment plans performed using two different treatment planning systems one incorporating Iridium-192 source and the other incorporating Cobalt-60 source.

## MATERIALS AND METHODS

This study is a retrospective analysis of 50 CT image-based ICBT treatment plans performed in Sagiplan (version 2.0) treatment planning system (TPS) using Co-60 HDR source with a step size of 3 mm. For each treatment plan planned in Sagiplan TPS, a comparative plan was generated in Brachy Vision (version 15.6.03) TPS with Ir-192 source. Both the TPSs used TG-43 formalism for dose calculation.

**GammaMed plus Ir-192 source:** The GammaMed Plus HDR remote after loading (M/S. Varian Medical Systems, USA) brachytherapy unit contains a single high activity Ir-192 source. This unit has 24 channels and the stepper movement mechanism moves the source from distal to proximal end. It can be programmed up to 60 dwell positions per channel with variable step size ranging from 1-10 mm in 1 mm increments. The combined length of the applicator and the source guide tube is maintained at 1300 mm. The source consists of 3.5 mm long Ir-192 core with a diameter of 0.60 cm enclosed in 0.90 mm diameter stainless steel (AISI 316L) capsule. Source is welded to the end of a flexible drive cable[14].

**Saginova Co-60 source:** The BEBIG Saginova HDR remote after loader (M/S. Eckert and Ziegler, BEBIG, GMBH) provides features like the ability to choose between an Ir-192 and a Co-60 source. BEBIG successfully designed and introduced the first miniaturized Co-60 source. The Saginova afterloader unit is loaded with a Co-60 source of an activity of up to 81.4 GBq and consists of 25 channels. The Saginova Co-60 source is composed of central cylindrical active core made of metallic Co-60 of length 3.5 mm and diameter of 0.5 mm. The active core is encapsulated in a cylindrical stainless-steel capsule 0.15 mm thick with an external diameter of 1 mm[14].

**Treatment planning and plan evaluation:** The CT scan images of 3 mm slice thickness were imported into the Sagiplan TPS. The HRCTV and critical organs (bladder, rectum, sigmoid) were contoured by the radiation oncologist. Initially planning was performed in Sagiplan TPS using Co-60 source with a prescription dose of 6 Gy/fraction to point A. The dose was calculated based on normalization to Manchester point A. A comparative plan was then generated in BrachyVision TPS using Ir-192 source by maintaining the same step size, dwell positions and dose to point A. The following Dose Volume Histogram (DVH) parameters were recorded and the treatment plans were compared based on these clinical parameters.

For HRCTV, dose to 90% ($D_{90}$) and dose to 50% ($D_{50}$) were estimated. Also volumes encompassed by 50% ($V_{50}$), 100% ($V_{100}$), 150% ($V_{150}$) and 200% ($V_{200}$) isodose lines were determined. For bladder, rectum and sigmoid, dose to 0.1 cc ($D_{0.1cc}$), 1 cc ($D_{1cc}$) and 2 cc ($D_{2cc}$) volumes of each OAR were evaluated. Also the difference in the time taken to deliver the same prescription dose with the full activity of both the sources was estimated.

**Statistical analysis:** An independent two-tailed Student's t-test was performed to compare the doses from the two radio isotopes and $p<0.05$ was considered for the determination of significance of statistical inferences.

## RESULTS

The mean dosimetric values of target volume (HR-CTV) and OARs (bladder, rectum and sigmoid) of 50 patients with intracavitary applicators were summarized and compared between Co-60 and Ir-192 sources. The planned images with the two sources in frontal and sagittal view are depicted in Fig. 1 and 2, respectively.

Dosimetric parameters of HR-CTV ($D_{90}$ and $D_{50}$) for Ir-192 and Co-60 radioisotopes are shown in Table 1. It is seen that there is an increase in the $D_{90}$ values of HRCTV by 1.95% in case of Co-60 as compared to Ir-192. There is no significant difference in the volumes enclosed by 200, 150, 100 and 50% isodose lines of both the sources.

Dosimetric values of the OARs such as bladder, rectum and sigmoid for Ir-192 and Co-60 are summarized in Table 2. The mean percentage difference in the dose values of 0.1 cc, 1 cc and 2 cc were recorded. Mean percentage difference of -3.04, -2.12 and 2.4% in the $D_{0.1cc}$, $D_{1cc}$ and $D_{2cc}$ respectively of bladder, 0.95, 3.0 and 5.31% in the $D_{0.1cc}$, $D_{1cc}$ and $D_{2cc}$

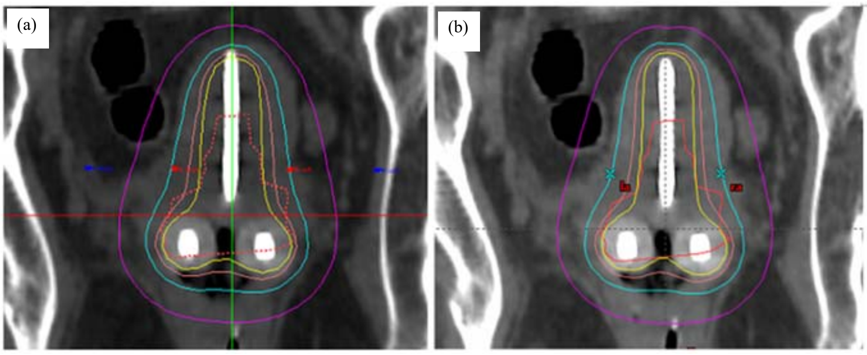


Fig. 1(a-b): Frontal view of the isodose distribution of intracavitary application planned using, (a) Co-60 and (b) Ir-192

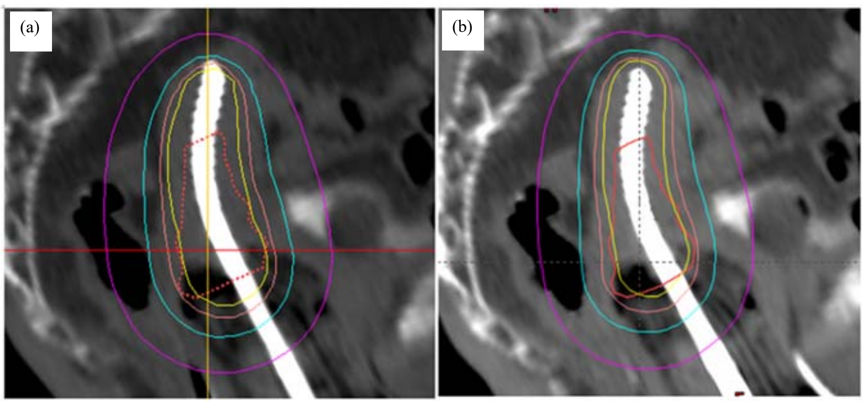


Fig. 2: Sagittal view of the Isodose distribution of intracavitary application planned using, (a) Co-60 and (b) Ir-192

Table 1: Dosimetric analysis of target volume and OARs for Ir-192 and Co-60 sources, *indicates statistically significant

| Structure | Parameters | Ir-192 | Co-60 | Difference (%) | p-value |
|---|---|---|---|---|---|
| | | Mean±SD (Gy) | | | |
| HRCTV | $D_{90}$ | 5.14±0.2 | 5.24±0.20 | 1.95 | 0.715 |
| | $D_{50}$ | 8.63±0.22 | 8.56±0.37 | -0.79 | 0.661 |
| Bladder | $D_{0.1cc}$ | 5.41±0.59 | 5.25±0.69 | -3.04 | 0.199 |
| | $D_{1cc}$ | 4.99±0.60 | 4.89±0.60 | -2.12 | 0.374 |
| | $D_{2c}$ | 4.58±0.64 | 4.69±0.54 | 2.40 | 0.355 |
| Rectum | $D_{0.1cc}$ | 5.18±0.75 | 5.23±0.58 | 0.95 | 0.714 |
| | $D_{1cc}$ | 4.90±0.75 | 5.05±0.58 | 3.00 | 0.271 |
| | $D_{2cc}$ | 4.73±0.75 | 4.98±0.55 | 5.31 | 0.057 |
| Sigmoid | $D_{0.1cc}$ | 4.28±0.27 | 4.69±0.63 | 9.43 | 0.00* |
| | $D_{1cc}$ | 4.08±0.28 | 4.41±0.62 | 8.02 | 0.001* |
| | $D_{2cc}$ | 3.90±0.29 | 4.25±0.61 | 9.00 | 0.00* |

Table 2: Dosimetric analysis of isodose volumes for Ir-192 and Co-60 sources

| Isodose volume | Ir-192 | Co-60 | Difference (%) | p-value |
|---|---|---|---|---|
| | Mean±SD (Gy) | | | |
| $V_{50}$ | 196.83±24.26 | 196.91±14.77 | 0.04 | 0.968 |
| $V_{100}$ | 73.5±16.45 | 73.98±14.19 | 0.66 | 0.887 |
| $V_{150}$ | 44.69±7.78 | 45.44±6.93 | 1.68 | 0.638 |
| $V_{200}$ | 28.07±5.38 | 29.08±4.89 | 3.60 | 0.341 |

respectively of rectum and 9.43, 8.02 and 9.0% in the $D_{0.1cc}$, $D_{1cc}$ and $D_{2cc}$, respectively of sigmoid were observed. The mean percentage difference in the doses to sigmoid were statistically significant. With regard to the difference in treatment time between the two sources it was found that the treatment time with Co-60 was about 1.2 times higher compared to that of Ir-192 for the same prescription dose to point A.

## DISCUSSIONS

Our results show that the dosimetric parameters for HRCTV, bladder and rectum in the ICBT cases studied were comparable for both Co-60 and Ir-192 sources. Doses to 90% of HRCTV was higher in case of Co-60 plans as compared to Ir-192 plans although the difference was not significant (p>0.05). Richter compared the physical properties of Co-60 and Ir-192 sources in HDR brachytherapy. Their results showed that the required activities for the same air kerma rate are lower for Co-60 source by a factor of 2.8. Monte Carlo calculations in their study demonstrated higher integral dose due to radial dose fall off for Ir-192 when compared to Co-60 within the first 22 cm from the source with normalization at 1 cm. This relationship is reversed at larger distances. However in the clinical examples identical dose distributions were seen in the treatment volume for both Co-60 and Ir-192 sources.

Tantivatana and Rongsriyam[15] compared the treatment outcomes between Co-60 and Ir-192 sources in stage IB2-IIIB cervical cancer patients. Their results showed that patients treated with both the sources were comparable in survival and toxicity outcomes. Also comparable results between the two sources were found in the dose parameters of HRCTV, bladder and rectum by Rathore *et al*.[16].

Relatively small differences in the dosimetric characteristics of three different applicator systems, the Morris, Fletcher and Henschke by Nath *et al*.[17] whereas a study conducted by Suryadevara *et al*.[18] showed favourable dosimetry with Fletcher's applicator for OAR doses without compromising the dose to point A.

Palmer *et al*.[19] evaluated the equivalence of Co-60 to Ir-192 for HDR cervical brachytherapy, through dose comparisons with 3D-DVH in standard and optimized plans. Their results showed small differences (p<0.01) in 3D dosimetry particularly 3.3% increase in $D_{2cc}$ of rectum when using Co-60 compared to Ir-192 with dose prescription to Point A and identical loading patterns. No significant difference was observed in this parameter when dose was prescribed to the HR-CTV using dwell-time optimization. Similarly, comparable results were obtained between Co-60 and Ir-192 sources in intracavitary cases by Shukla *et al*.[16].

Wen *et al*.[20] studied the differences between Co-60 and Ir-192 HDR IC-ISBT plans in terms of radiobiological and dosimetric parameters. They found that Compared with Ir-192, the use of Co-60 for HDR IC-ISBT can ensure a similar tumour control probability while providing better protection to the OARs. In another study Wen *et al*.[21] performed a comparative analysis of Co-60 and Ir-192 sources in HDR BT for cervical cancer in terms of both dosimetry and clinical treatment. Their results showed that this treatment is safe and it is feasible to use Co-60 as an alternative source.

The values of radial dose function for distances above 22 cm for HDR flexi Co-60 source was found to be higher than that of the HDR microSelectron Ir-192 source in a study by Gebremariam *et al*.[22]. The anisotropic values sharply increased to the longitudinal sides of HDR flexi Co-60 source and the increase was comparatively sharper to that of the Ir-192 source. The study concluded that the primary photons from the lower-energy microSelectron Ir-192 source have a limited range and are partially attenuated which could be inferred from the results of radial and anisotropic dose distribution functions.

Our study showed significant difference between the two sources in the dose to 0.1 cc, 1 cc and 2 cc volumes of sigmoid. This could be explained based on the isodose distribution of Co-60 source which shows a small bulge along the longitudinal axis while Ir-192 shows a dip in the same direction[13,21]. As our treatment plans are not optimized, these higher OAR doses are observed. This could be reduced by using suitable optimization techniques in the actual patient plan for treatment. No significant differences were observed in the volumes enclosed by the isodose lines of the two sources.

Our results from the intracavitary treatment plans show that the dosimetric parameters for Co-60 and Ir-192 radioisotopes are comparable with regard to target and OAR doses. Significant differences between the two sources were observed only in doses to 2cc of sigmoid which could be due to the bulge in the isodose lines along the longitudinal axis of the Co-60 source. Also the plans in the present study were not optimized. We can conclude that although minor differences exist between Ir-192 and Co-60 sources, both the sources can provide similar results in intracavitary applications for optimized plans and hence either of the radioisotopes may be preferred for HDR brachytherapy treatments[23,24].

## ACKNOWLEDGMENTS

Authors would like to express sincere thanks to Dr Vijay CR, Associate Professor, Department of Biostatistics, Kidwai Memorial Institute of Oncology, Bangalore for supporting in statistical work involved in this study.

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