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Original research article

Dosimetric analysis of Co-60 source based high dose rate (HDR) brachytherapy: A case series of ten patients with carcinoma of the uterine cervix



Om Prakash Gurjar^{a,*}, Manika Batra^a, Priyusha Bagdare^a,
Sandeep Kaushik^b, Atul Tyagi^b, Ayush Naik^a, Virendra Bhandari^a,
Krishna Lal Gupta^a

^a Roentgen-SAIMS Radiation Oncology Centre, Sri Aurobindo Institute of Medical Sciences, Indore, India

^b Roentgen-BLK Radiation Oncology Centre, BLK Super Specialty Hospital, New Delhi, India

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ABSTRACT

Aim: To analyse the dosimetric parameters of Co-60 based high dose rate (HDR) brachytherapy plans for patients of carcinoma uterine cervix.

Background: Co-60 high dose rate (HDR) brachytherapy unit has been introduced in past few years and is gaining importance owing to its long half life, economical benefits and comparable clinical outcome compared to Ir-192 HDR brachytherapy.

Materials and methods: A study was conducted on ten patients with locally advanced carcinoma of the uterine cervix (Ca Cx). Computed tomography (CT) images were taken after three channel applicator insertions. The planning for 7 Gray per fraction (7 Gy/#) was done for Co-60 HDR brachytherapy unit following the American Brachytherapy Society (ABS) guidelines. All the patients were treated with 3# with one week interval between fractions.

Results: The mean dose to high risk clinical target volumes (HRCTV) for D₉₀ (dose to 90% volume) was found to be 102.05% (Standard Deviation (SD): 3.07). The mean D_{2cc} (dose to 2 cubic centimeter volume) of the bladder, rectum and sigmoid were found to be 15.9 Gy (SD: 0.58), 11.5 Gy (SD: 0.91) and 4.1 Gy (SD: 1.52), respectively.

Conclusion: The target coverage and doses to organs at risk (OARs) were achieved as per the ABS guidelines. Hence, it can be concluded that the Co-60 HDR brachytherapy unit is a good choice especially for the centers with a small number of brachytherapy procedures as no frequent source replacement is required like in an Ir-192 HDR unit.

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* Corresponding author at: Roentgen-SAIMS Radiation Oncology Centre, Sri Aurobindo Institute of Medical Sciences, Indore 453111, India. Tel.: +91 8871883903.

E-mail addresses: ominbarc@gmail.com (O.P. Gurjar), manikabatra@gmail.com (M. Batra), pink2006@gmail.com (P. Bagdare), ri_ha@rediffmail.com (S. Kaushik), rosindoresearch@gmail.com (A. Tyagi), ayushnaik@gmail.com (A. Naik), virencancer@yahoo.co.in (V. Bhandari), drklguptaindore@yahoo.com (K.L. Gupta).
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Table 1 – Physical properties of Ir-192 and Co-60 radioisotopes.^{5,6,10}

Properties	Cobalt-60	Iridium-192
Half life	5.26 years	73.8 days
Photon energy (MeV)	1.25 (mean)	0.38 (mean)
Half value layer (mm lead)	11	2.5
Exposure rate constant (R-cm ² /mCi-h)	13.07	4.69
Maximum specific activity (GBq/mg)	41.91	340.98
Inner length	3.5 mm	3.6 mm
Outer length	5 mm	4.5 mm
Inner diameter	0.5 mm	0.65 mm
Outer diameter	1 mm	0.9 mm

1. Background

Carcinoma of the uterine cervix (Ca Cx) is the fifth most common cancer worldwide, the second most common cancer in women and the most common cause of death in cancer patients in the developing countries. The most important risk factor for cervical intraepithelial neoplasia and invasive cervical cancer is the sexually transmitted human papilloma virus (HPV) infection.¹ The annual incidence of Ca Cx is approximately 510,000 new cases worldwide, with approximately 288,000 deaths.² The Ca Cx occurs in the reproductive period of a woman's life. The incidence rises in 30–34 years of age and peaks at 55–65 years, with a median age of 38 years (age 21–67 years).

Usually, the Ca Cx patients are treated with weekly chemotherapy concurrent with external beam radiotherapy (EBRT) for 50 Gray in 25 fractions (50 Gy/25#) at the rate of 2 Gy/#³ followed by biological equivalent dose of 30–35 Gy by 3# of 7–8.5 Gy or 2# of 9 Gy by high dose rate (HDR) brachytherapy. Brachytherapy has an inverse square law as the most dominant physical effect, whereby radiation dose is inversely proportional to the square of the distance from the source. In practical terms, this allows for a very high dose to the tumor with relative sparing of the surrounding normal structures, which is the only demonstrated method of providing the high dose required to control Ca Cx (>80 Gy) without exceeding the dose tolerance of the bladder and rectum.⁴

Ir-192 HDR brachytherapy units has been used for a long time. Co-60 HDR unit has been introduced in past few years and is gaining importance owing to its long half-life. Co-60 with enhanced activity allows miniaturized sources that are equivalent to conventional Ir-192 sources (as shown in Table 1) with the same shape and diameter of applicators and similar application techniques.⁶ The Co-60 and Ir-192 sources decay with different half-lives ($T_{1/2}$), the Co-60 source replacement is done after five years while Ir-192 source is replaced at every four months and both sources have different initial conditions. The variation in treatment time with time for the two sources is as shown in Fig. 1.⁷

Long half life of Co-60 provides relaxation in terms of repeated source replacement, documentation and administrative workload, specially related to competed authority, and thus, above all, it is economical as compared to Ir-192 HDR brachytherapy unit. Although, due to higher energy of Co-60

(1.25 MeV) than that of Ir-192 (0.38 MeV), the brachytherapy room with a larger wall thickness is required which increases the initial setup cost of Co-60 HDR brachytherapy unit.⁸ Co-60 HDR brachytherapy offers a clinical outcome equivalent to Ir-192 HDR brachytherapy.^{6,9} The physical properties of Co-60 and Ir-192 HDR brachytherapy sources are mentioned in Table 1.

2. Aim

To analyse the dosimetric parameters of Co-60 based high dose rate (HDR) brachytherapy plans for patients of carcinoma uterine cervix.

3. Materials and methods

The prospective study has been conducted on ten locally advanced Ca Cx patients. Approval from the institutional ethical committee was taken and consent from all the patients was received after explaining the pros and cons of the procedure. The selection criterion for the patients was histologically proven locally advanced Ca Cx stage III-b receiving concurrent chemoradiotherapy with Karnofsky performance status >70%. The patients who had undergone hysterectomy or with distant metastasis or other co-morbidities were excluded from the study.

The patients were initially given 50 Gy/25# with medical linear accelerator Clinac DMX (Varian Medical System Inc., Palo Alto, CA) along with concurrent chemotherapy with weekly injection cisplatin 40 mg/m² following which they were assessed for intra cavitory radiotherapy (ICRT). The patients with favorable anatomy for ICRT were included in the study and were planned for ICRT after one week from completion of EBRT.

To start with, the patient's fitness for procedure was assessed by the anesthetist. An ultrasonography (Phillips iu22, Bothwell, WA, USA) of the whole abdomen was done to assess the length and position of the uterus.

The necessary quality assurance (Q.A.) tests of HDR Brachytherapy unit (BEBIG GyneSource HDR, Eckert & Ziegler BEBIG, Germany) having Co-60 radioisotope (model Co0.A86, Eckert & Ziegler BEBIG, Germany) was done and then the patient was taken to the operation theater. The three channel applicator set (tandem and ovoids; Eckert & Ziegler BEBIG, Germany) was checked for its integrity. The patient was given a short general anesthesia. The patient was given anesthesia then she was put in a lithotomy position. The body parts in and near the vaginal region were cleaned and then draped. The length of the uterus was measured with the uterine sound. The appropriate length and position of the uterus was confirmed, the cervical os was dilated and the central tandem was inserted in the uterine cavity. After this, the ovoids with the lateral tandems were placed in the lateral fornices and fixed to the central tandem. This apparatus was held in position with the help of a T bandage tied to the abdomen. The patient was kept under observation for 15 min post procedure and then shifted for computed tomography (CT) scan of the pelvic area using Siemens SOMATOM definition AS scanner (Siemens Medical systems, Germany). CT images of 3 mm slice

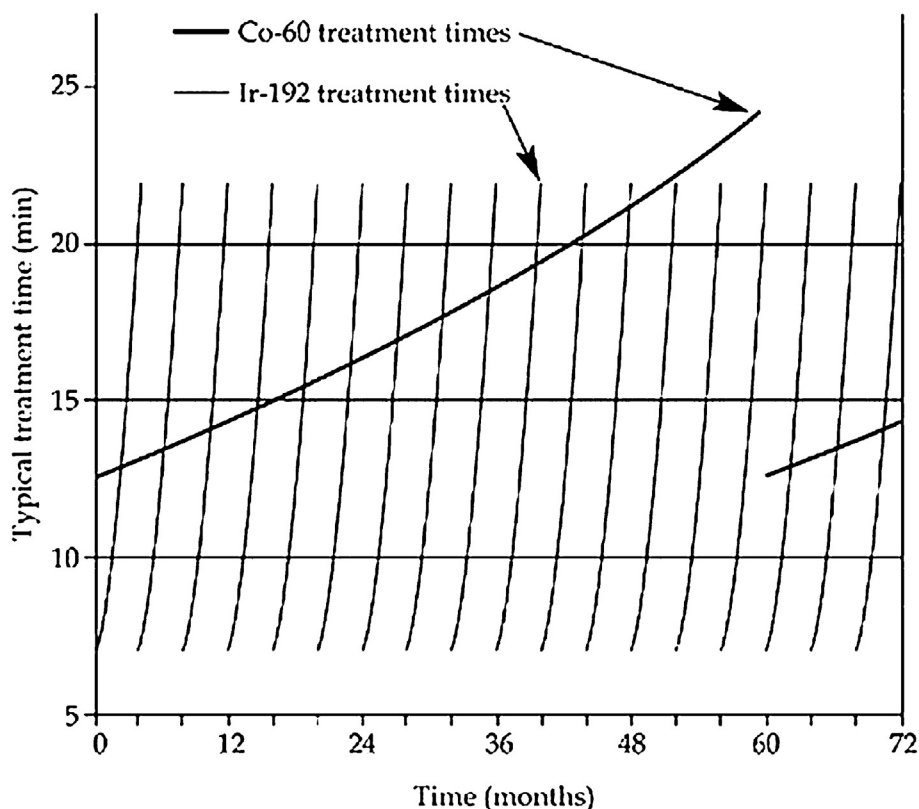


Fig. 1 – A comparative graph for total treatment time by Co-60 and Ir-192 sources in a typical cervix HDR brachytherapy, as a function of time over six years period. Co-60 source replacement is done after five years while Ir-192 source is replaced at every four months.⁷

thickness were taken. The CT images were imported on treatment planning system (TPS) HDR Plus (Eckert & Ziegler BEBIG, Germany).

Since the HDR brachytherapy procedures were CT based, the target delineation and planning for all the patients was done as per the American Brachytherapy Society (ABS) guidelines. High risk clinical target volume (HRCTV) included the entire uterine cervix and any parametrial extension. Organs at risk (OARs) such as the bladder, rectum and sigmoid were also delineated.

The planning for 7 Gy/# was done following the ABS guidelines. The three channel applicators viz. left lateral, central and right lateral applicators were selected and aligned with the respective applicators seen on CT images. The point 'A' and point 'B' were marked by the Manchester system. Step size of 3 mm was selected and required length of each applicator was activated depending upon the case. The 100% dose was calculated on point 'A' and then the 100% isodose line was adjusted using the available tools on TPS in such a way that HRCTV was covered at least by 90% of the isodose line. The 100% isodose line was adjusted to save the bladder, rectum and to reduce the unwanted dose spillage outside the HRCTV volume. Since the planning was three dimensional imaging based, dose to HRCTV was given importance rather than point 'A' and 'B'. The doses to target and OARs were analyzed and noted. Fig. 2(a) shows the applicators position and Fig. 2(b) shows the pear shaped dose distribution.

The patient was shifted to the brachytherapy room and the source guide tubes were connected to the respective applicators. After checking the connections of guide tubes with HDR unit and applicators, the treatment plan was executed. All the patients were treated with 3# with one week interval between fractions.

4. Results

The mean dose to high risk clinical target volumes (HRCTV) for D_{90} (dose to 90% volume) was found to be 102.05% (Standard Deviation (SD): 3.07). The mean D_{2cc} (dose to 2 cubic centimeter volume) of the bladder, rectum and sigmoid were found to be 15.9 Gy (SD: 0.58), 11.5 Gy (SD: 0.91) and 4.1 Gy (SD: 1.52), respectively. Fig. 3 shows the dose distribution in the frontal, sagittal and axial view. The detailed results of the study are given in Table 2. The dose to D_{2cc} of the bladder, rectum and sigmoid by EBRT was 50 Gy. The total dose by HDR brachytherapy and EBRT is given in Table 3.

5. Discussion

The results of this study are well in accordance with the ABS guidelines (80–90 Gy for D_{90} HRCTV, 70–75 Gy for D_{2cc} to the rectum and sigmoid and approximately 90 Gy for D_{2cc} to the bladder).^{11–13} The doses to the rectum, bladder and sigmoid

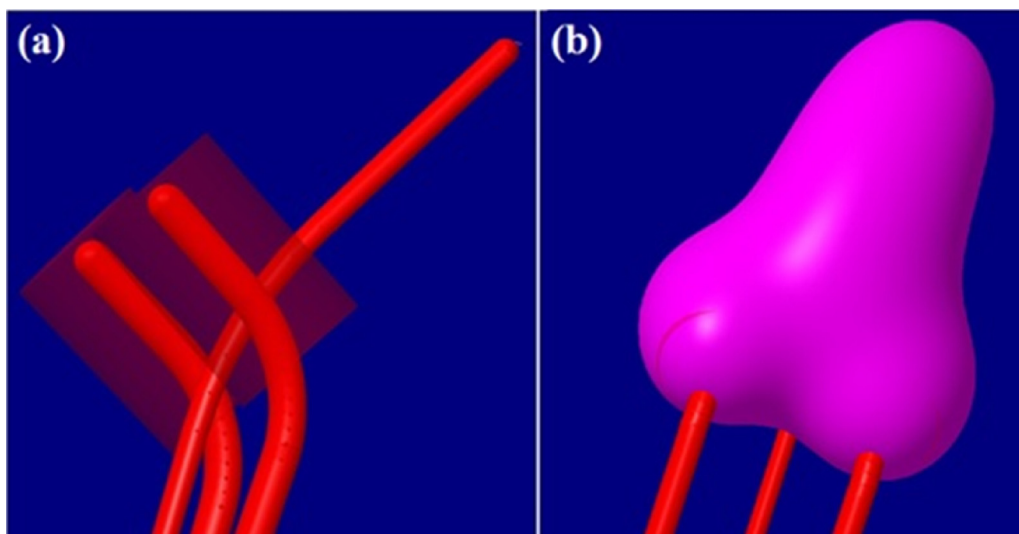


Fig. 2 – (a) Three channel applicator position in sagittal view and (b) pear shaped dose distribution.

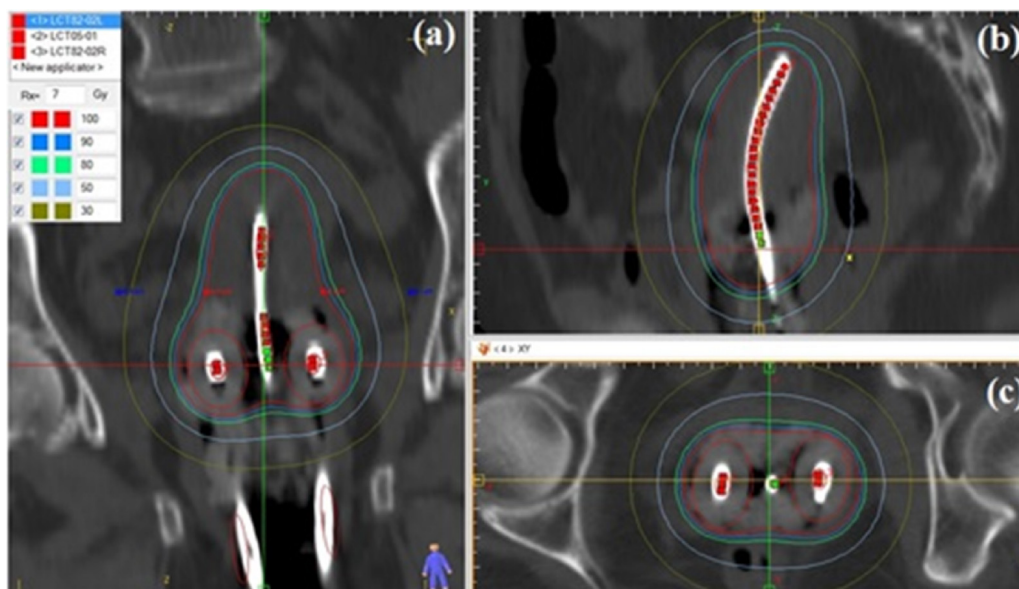


Fig. 3 – Dose distribution in (a) frontal view, (b) sagittal view and (c) axial view.

are well within the tolerance limit without compromising the doses to target. Also the planning dosimetric parameters of this study concurred with the results of already published studies on Ir-192 HDR brachytherapy unit based planning. Bahadur et al.¹⁴ has presented similar results with Ir-192 HDR brachytherapy in Ca Cx with target coverage of 100% to D_{90} for HRCTV and D_{2cc} of the rectum and bladder was 82.85% and 105.71, respectively.

The use of Co-60 HDR brachytherapy unit is comparable with the Ir-192 HDR brachytherapy unit. Palmer et al.⁷ in their study concluded that Co-60 may be used as an effective alternative to Ir-192 for HDR cervix brachytherapy, producing similar plans of equivalent D_{90} , but with logistical benefits. There is a small dose increase along the extension of the source axis when using Co-60 compared to Ir-192, leading to small rectal dose increases for identical loading patterns.

This can be eliminated by planning optimization techniques. Also the treatment time by Co-60 HDR brachytherapy source is only 1.7 times more than that with Ir-192 HDR brachytherapy source with the initial activities.⁶

The doses to organs at large distances from the applicators by Co-60 is the point of discussion compared to Ir-192, Venselaar et al.¹⁵ shown in their study that for distances of up to 20 cm, Ir-192 source has slightly higher dose values (ratio of 1.14 at 10 cm and 1.05 at 20 cm) suggesting lower dose in peripheral organs at risk outside the treated volume but for larger distances, Co-60 source has higher dose values (ratio of 1.16 at 30 cm, 1.68 at 45 cm and 2.57 at 60 cm) suggesting higher integral dose for Co-60 sources.

The study of Ntekim et al.¹⁶ on acute gastrointestinal (GI) and genitourinary (GU) toxicity associated with Co-60 source in the brachytherapy of Ca Cx shows that the median total

Table 2 – Dosimetric parameters of plans done for ten patients.

Patient serial number	D ₉₀ HRCTV (%)	D _{2cc} bladder (%)	D _{2cc} rectum (%)	D _{2cc} sigmoid (%)
1	99.7	79	57.5	20.8
2	99.2	79.2	59.5	25.2
3	97.5	71.8	52.1	34.6
4	105.9	76.1	60.5	11.5
5	104	76.3	46.1	8.5
6	106	73.8	53.2	16.7
7	99	76.9	53	17
8	104.2	77.2	56.6	22
9	101.5	79	54	19
10	103.5	71	55.6	20.2
Mean	102.05	76.03	54.81	19.55
SD	3.07	2.95	4.15	7.21

Table 3 – Total doses received by HRCTV and OARs.

Patient	D ₉₀ HRCTV (Gy)			D _{2cc} bladder (Gy)			D _{2cc} rectum (Gy)			D _{2cc} sigmoid (Gy)		
	HDR	EQD2	Total ^a	HDR	EQD2	Total ^a	HDR	EQD2	Total ^a	HDR	EQD2	Total ^a
1	20.7	29.2	79.2	16.5	21.3	71.3	12	14	64	4.4	5.3	55.3
2	20.7	29.2	79.2	16.5	21.3	71.3	12.6	14.9	64.9	5.3	6.8	56.8
3	20.4	28.6	78.6	15	18.8	68.8	10.8	12.2	62.2	7.3	10.5	60.5
4	22.2	32.2	82.2	15.9	20.3	70.3	12.6	14.9	64.9	2.4	2.5	52.5
5	21.9	31.6	81.6	15.9	20.3	70.3	9.6	10.6	60.6	1.8	1.8	51.8
6	22.2	32.2	82.2	15.6	19.8	69.8	11.1	12.7	62.7	3.5	4.0	54.0
7	20.7	29.2	79.2	16.2	20.8	70.8	11.1	12.7	62.7	3.6	4.1	54.1
8	21.9	31.6	81.6	16.3	20.8	70.8	12	14	64	4.6	5.6	55.6
9	21.3	30.4	80.4	16.5	21.3	71.3	11.4	13.1	63.1	4.0	4.7	54.7
10	21.6	31	81	15	18.8	68.8	11.7	13.6	63.6	4.2	5.0	55.0
Mean	21.4	30.5	80.5	15.9	20.4	70.4	11.5	13.3	63.3	4.1	5.0	55.0
SD	0.69	1.38	1.38	0.58	0.96	0.96	0.91	1.31	1.31	1.52	2.41	2.41

HRCTV = high risk clinical target volume; D₉₀ = dose to 90% of HRCTV; D_{2cc} = dose to 2cc volume; HDR = high dose rate brachytherapy; EQD2 = dose equivalent to 2 Gy per fraction.

^a Total dose by external beam radiotherapy (50 Gy in 25 fractions) & by HDR brachytherapy.

biological effective dose (BED) for tumor was 86.2 (84.4–88.8) while that for the rectum was 124.4 (120–133). 3% of patients had grade 3 gastrointestinal toxicity while all others had ≤grade 2 GI and GU toxicity and this is comparable with previous results. Therefore, Co-60 as HDR brachytherapy source is tolerable.

6. Conclusion

In all the plans of the Co-60 source based HDR brachytherapy of Ca Cx, the target coverage and doses to OARs were achieved as per the ABS guidelines. Hence, it can be concluded that the Co-60 HDR brachytherapy unit is a good choice especially for the centers with small number of brachytherapy procedures as no frequent source replacement is required like in an Ir-192 HDR unit.

Conflict of interest

None declared.

Financial disclosure

None declared.

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