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Dosimetric Analysis of 3D-CT Image Based High Dose Rate Brachytherapy Treatment Planning of Carcinoma Uterine Cervix: Initial Experiences at Central India Government Institute

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Abstract

Background: Conventionally, the dose calculation of intracavitary brachytherapy (ICBT) is carried out using two dimensional (2D) orthogonal x-ray films. In comparison to conventional 2D, three dimensional (3D) image based planning is providing volumetric dose to target and organs at risk (OARs). Due to logistical reasons, it is not feasible to perform 3D image based brachytherapy planning in resource setting radiotherapy centers.

Aim: This study aimed to analyze the dose volume parameters (DVH) for target and OARs in high dose rate (HDR) ICBT treatment planning of carcinoma uterine cervix (Ca-Cx) patients. Our initial experiences of computed tomography (CT) image based ICBT planning.

Materials and Methods: Retrospectively 39 CT image based plans of 13 patients (total 13x3=39 CT) of Ca-Cx were evaluated, who have already treated with Ir-192 HDR brachytherapy. The dose of 7 Gy/fraction for 3 fractions was prescribed and calculated on point 'A'. The 100% isodoseline of prescribed dose was adjusted using geometrical tools of treatment planning system (TPS) in such a manner that high risk clinical target volume (HR-CTV) was encompassed by at least 90% of isodose line with keeping OARs doses within tolerance limit. The dose volume parameters HR-CTV D_{90}, HR-CTV D_{100} and average point 'A' for target and D_{2CC} for OARs were calculated and evaluated.

Results and Discussion: The combined mean dose for dosimetric parameters HR-CTV D_{90}, HR-CTV D_{100} and average point 'A' were found to be 100.82 Gy (S.D.: ± 6.08), 70.95 Gy (S.D.: ± 2.76) and 79.46 Gy (S.D.: ± 0.66) respectively. The combined D_{2CC} mean dose of bladder, rectum and sigmoid colon were found to be 68.89 Gy (S.D.: ± 8.76), 63.74 Gy (S.D.: ± 3.82) and 73.20 Gy (S.D.: ± 3.04) respectively.

Conclusion: In a resource setting radiotherapy centers 3D-CT image may be used as a moderate option of imaging for ICBT treatment planning of Ca-Cx.

Keywords: Dosimetric analysis; Computed tomography; High dose rate; Brachytherapy; Carcinoma uterine cervix

Introduction

Cervical carcinoma is the second most common malignancy in the women worldwide, after breast cancer, this accounts nearly 5,00,000 new cases and 2,50,000 death per year (National Institute of Health consensus Development Conference statement on cervical Cancer) [1]. Of these, 80% occur in developing countries and 20% in developed countries as reported by Parkins study [2]. Carcinoma uterine cervix (Ca-Cx) is one of the most common cancers among rural Indian women [3]. Concurrent chemo radiation is standard treatment option for locally advanced cervical carcinoma. Brachytherapy is integral part of treatment in cervical cancer patients when treated with curative intent. When starting the brachytherapy component of treatment, one must first decide on whether to use high dose rate (HDR) or low dose rate (LDR) brachytherapy. Historically, cervical brachytherapy used exclusively LDR sources. Treatments were delivered over 1-2 fractions, with treatment times of (typically) 1-3 days, requiring prolonged patient immobilization.

Since last two decades, there has been increasing adoption and utilization of HDR, as opposed to LDR. Eighty-five percent of respondents to a recent American Brachytherapy Society (ABS) survey reported having HDR at their institution [4] with HDR, a remote after loading technology allows a small iridium-192 (Ir-192) source attached to the end of a cable to be robotically driven through multiple channels, stopping at predetermined points (dwell positions) for varied lengths of time.

HDR brachytherapy is delivered dose at a point A with dose rate of >12 Gy/hour, primarily using the Ir-192 isotope. The advantages of HDR include the precise positioning of the source, infinitely variable dwell times and dwell positions – allowing for "dose sculpting" – shorter treatment times (minutes versus days), and the protection of health care personnel from radiation exposure [5-7]. Overall clinical outcomes and toxicities are felt to be almost similar with both HDR and LDR [5].

The major advantage of intracavitary brachytherapy (ICBT) is

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that it delivers a very high dose to tumor volume with rapid dose falls of outside hence less dose to adjacent organs at risk (OARs) namely bladder, rectum and sigmoid colon. The evaluation of dose received to OARs is very essential because these are dose limiting structures in ICBT. Conventionally, the dose calculation of ICBT is carried out using orthogonal x-ray where point doses to OARs are calculated as per International Commission on Radiation Units and Measurements (ICRU) 38 recommendations [8]. However, the point doses to OARs may not represent volumetric dose to organs. In comparison to conventional two dimensional (2D) planning, three dimensional (3D) image based planning is providing volumetric dose to target and OARs.

With the advancement in imaging technology the use of 3D image from computed tomography (CT) and magnetic resonance imaging (MRI) are increasing globally in HDR brachytherapy planning. The worldwide availability of CT scanners made it common 3D imaging modality for image guided brachytherapy planning. Recently, published guidelines ABS [9], Gynaecological-European Group of Curie-therapie European Society for Therapeutic Radiology and Oncology (GEC-ESTRO) [10,11] and ICRU 89 [12] strongly recommended individualized 3D image based brachytherapy planning for Ca-Cx.

In comparison to conventional 2D planning, 3D image based treatment planning is fruitful for accurate evaluation of dose delivered to target and surrounding OARs. Albeit, a more accurate estimation of dose received to OARs may helpful in improving therapeutic ratio, in terms of better treatment outcomes and reducing the complications. Apart from, with 3D image based planning it may be possible to estimate the volumetric dose response relationship by calculating the radiotherapy doses including external beam radiotherapy (EBRT) and ICBT. In our institute 3D-CT image based HDR ICBT treatment plans was comes in practice from January 2017 and earlier standard library plan was used for ICBT treatment.

This study aimed to analyze the dose volume parameters (DVH) for target and OARs in HDR ICBT treatment planning of Ca-Cx to find out feasible mode of imaging for resource setting radiotherapy centers. Our initial experiences of 3D-CT image based ICBT planning.

Materials and Methods

Thirteen patients with biopsy proven squamous cell Ca-Cx with stage IIA, IIB, IIIB and IVA were entered into the protocol who were treated with EBRT either at our medical college or refer from other institute for brachytherapy. Retrospectively 39 CT image-based plans of 13 patients (total 13x3=39 CT) of Ca-Cx were evaluated.

Eligibility criteria

i. Biopsy proven squamous cell carcinoma.

ii. Age between 35-60 years.

iii. hematology and biochemistry parameter are <1.5 ULN.

iv. No history of prior radiation therapy to pelvis.

Pre-treatment evaluation

i. Complete history and physical examination.

ii. X- ray pelvis, X-rays chest, Ultra sonograph (USG) abdomen and pelvis, CT scan and MRI of pelvis also done.

iii. Laboratory studies including routine investigation like Hemoglobin estimation, total leukocyte count; differential count and platelet count; and liver functions test, biochemical analysis.

iv. Clinical staging based on the International Federation of Gynaecology and Obstetrics (FIGO) staging.

Treatment designed

The treatment protocol schedule consisted of both EBRT with brachytherapy.

Radiotherapy planning

EBRT dose, 46 Gy/23 fractions to whole pelvis followed by 4 Gy/2 fraction with midline structures shielding, was delivered using either Cobalt-60 unit or 6MV linear accelerator one fraction per day, five days in a week followed by EBRT all patients were planned for ICBT treatments of 3 fractions of 7 Gy each (total 21 Gy) to reference point 'A' (2 cm superior and 2 cm lateral to the cervical Os) on weekly basis.

The applicator insertion was done in brachytherapy operation theater room. Fletcher style applicator set with fixed geometry (part no. GM11000810) were used in this study. The Gamma Med Fletcher applicator set was made by Varian Medical Systems, Inc. Palo Alto CA9430 USA. The fixed geometry applicator containing one tandem (6.0 cm uterine length and 15^0 angles) and two ovoids diameter range (1.5 cm to 2.5 cm) were used in all patients. Appropriate vaginal packing was done using Betadine soaked gauge for confinement and to avoid slippage of applicator geometry. In all patients Foley's catheter was inserted into urinary bladder and bladder was left to drain.

After applicator insertion patients were transferred into CT simulator (GE WIPRO DISCOVERY CT) room for acquiring 3D axial CT images. CT images were acquired from umbilicus to mid-thigh with slice thickness 2.5 mm. In whole procedure special attention was taken care to minimize applicator displacement during patient shifting and image acquisitions. All images were imported into Brachy Vision vs. 8.9 (Varian Medical Systems, Palo Alto, CA, USA) treatment planning system using CD/DVD. Reconstruction of applicator and contouring of tumor (HR-CTV) and OARs (bladder, rectum and sigmoid colon) were done by Radiation oncologist following ABS [9] and GEC-ESTRO [10-12] guidelines. Contouring of HR-CTV on axial CT images was done according to Viswanathan contouring guidelines [13]. Figure 1 shows the three channel applicator (Tandem & ovoids), target (HR-CTV) and OARs (bladder, rectum and sigmoid colon) position in axial, frontal, sagittal and model view respectively. All applicator insertion and contouring were done by single Radiation oncologist and treatment planning was by single Medical Physicist to avoid inter personal variations.

The dose of 7 Gy/fraction was prescribed and calculated on point 'A' as per ABS [9] guidelines. The 100% isodoseline of prescribed dose was adjusted using geometrical tools of treatment planning system (TPS) in such a manner that HR-CTV was encompassed by at least 90% of isodose line with keeping OARs doses within tolerance limit. Figure 2 shows the typical isodose distribution in 3D-CT image based ICBT treatment plan of a representative patient. The ICBT plans were optimized in such a way that total EQD_2 (equivalent dose in 2 Gy fractions) doses for OARs including EBRT and ICBT were kept ≤ 90 Gy for bladder and ≤ 75 Gy for rectum and sigmoid colon. For calculation of combined dose from EBRT and ICBT, it was assumed that from EBRT, OARs received 46 Gy because after 46 Gy midline structure was shielded and target (HR-CTV and point 'A') received 50 Gy. For adding dose of HDR ICBT to EBRT, EQD_2 according to linear quadratic (LQ) [14] model was calculated using following formula:

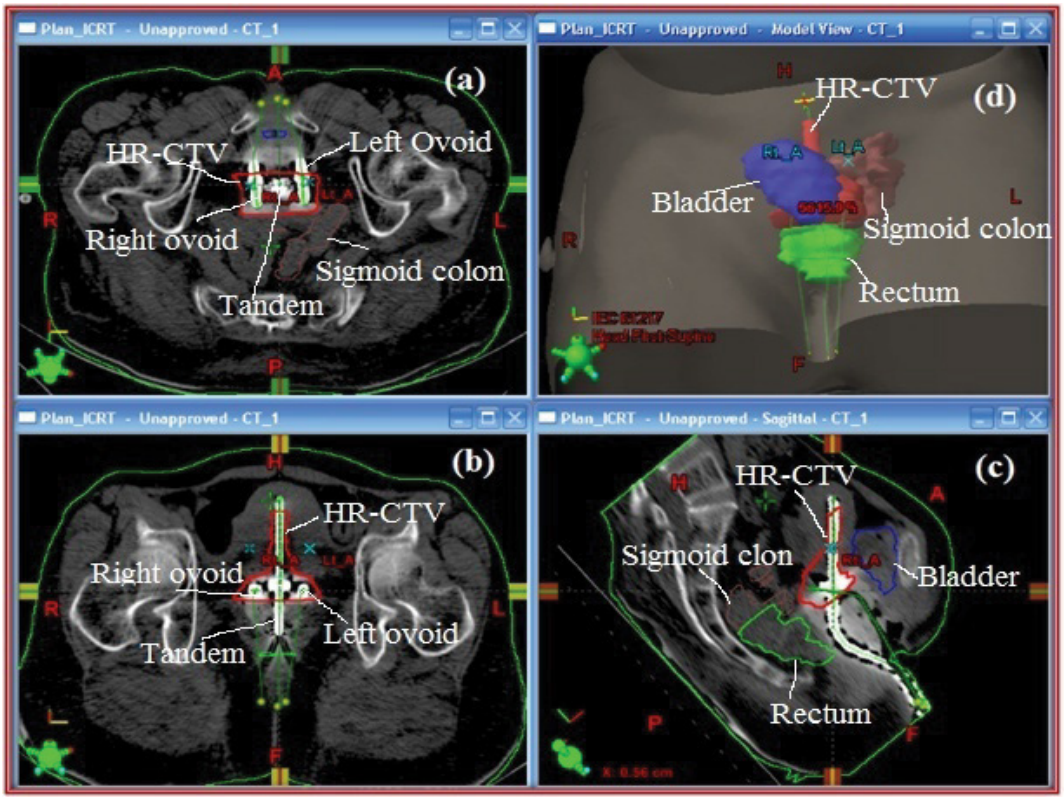

Figure 1: Illustration of three channel applicator (Fletcher fixed geometry Tandem & Ovoids), Target (HR-CTV) and Organs at risk (bladder, rectum and sigmoid colon) in (a) axial view, (b) frontal view, (c) sagittal view and (d) model view.

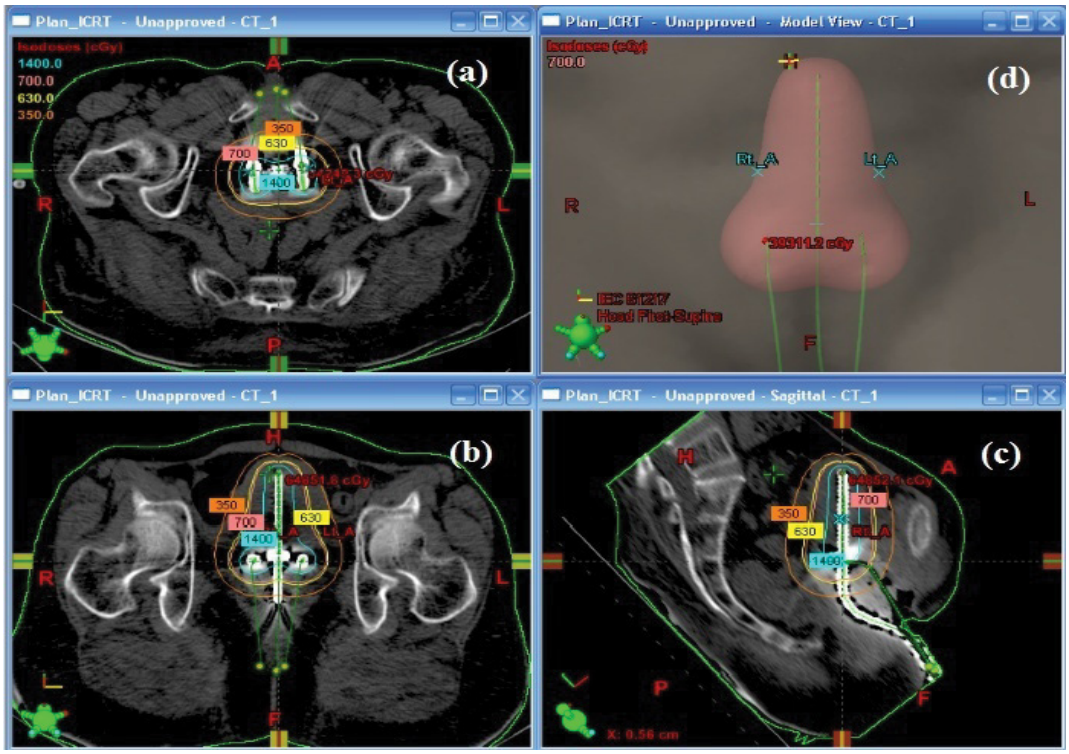

Figure 2: Isodose distribution in (a) Axial view, (b) Frontal view, (c) Sagittal view and (d) Pear shape in model view.

$$EQD_2 = \frac{d(1+\frac{d}{\alpha/\beta})}{(1+\frac{d}{\alpha/\beta})}$$

Where d denotes dose per fraction and α/β represents tissue - specifying factor [14]. For calculation of tumor (HR-CTV and point 'A') dose α/β was taken 10 Gy and for OARs (bladder, rectum and sigmoid dose) it was taken 3 Gy. As individualized CT image based treatment plan of each fraction was done, EQD_2 dose for target and OARs were calculated for each fraction and added together.

As per recent established guidelines (ABS, GEC-ESTRO and ICRU 89) the recommended dose volume parameters is D_{2CC} (the minimum dose received by maximum volume of 2 cc) for OARs (bladder, rectum and sigmoid colon). For target (HR-CTV) the recommended dose volume parameters is D_{90} and D_{100} (the minimum dose delivered to 90% and 100% of respective volume of HR-CTV). The dose volume parameter for target and OARs was calculated using cumulative dose volume histogram (cDVH). In this study the DVH parameters HR-CTV D_{90}, HR-CTV $D_{100}$and average point 'A' dose for target and D_{2CC} for OARs were calculated and evaluated.

For statistical analysis, Statistical software package SPSS version 20 (IBM corporation, USA) was used. The descriptive analysis was performed to determine the mean and standard deviation mean (± S.D) doses for OARs and target.

Results

The dosimetric parameters D_{90} (%), D_{100} (%) and average point 'A' dose for target (HR-CTV) of individual plans for each patient are summarized in Table 1. The mean dose to HR-CTV for D_{90} was found to be 140.67% (S.D.: ± 11.89%), 141.26% (S.D.: ± 12.01%) and 149.66% (S.D.: ± 17.83%) in first, second and third fraction of treatment plans respectively. The mean dose to HR-CTV for D_{100} was found to be 76.28% (S.D.: ± 9.89%), 72.21% (S.D.: ± 8.80%) and 83.03% (S.D.: ± 12.96%) in first, second and third fraction of treatment plans respectively. The mean dose for average point 'A' dose was found to be 99.05% (S.D.: ± 2.31), 98.88% (S.D.: ± 3.00) and 100.15% (S.D.: ± 1.87) in first, second and third fraction of ICBT treatment plans respectively.

The dosimetric parameters D_{2CC} for OARs of individual plans for each patient are summarized in Table 2. The mean D_{2cc} dose for bladder was found to be 4.66 Gy (S.D.: ± 1.46), 4.68 Gy (S.D.: ± 1.14) and 4.85 Gy (S.D.: ± 1.25) during first, second and third fraction of ICBT plans respectively. For rectum, the mean D_{2cc} dose was found to be 3.84 Gy (S.D.: ± 0.70), 4.29 Gy (S.D.: ± 0.71) and 4.17 Gy (S.D.: ± 0.46) during first, second and third fraction of ICBT plans respectively. For sigmoid colon, the mean D_{2cc} dose was found to be 5.45 Gy (S.D.: ± 0.45), 5.34 Gy (S.D.: ± 0.43) and 5.27 Gy (S.D.: ± 0.55) during first, second and third fraction of ICBT plans respectively.

From EBRT the D_{2CC}dose for bladder, rectum and sigmoid colon was 46 Gy. While the dose for D_{90} and D_{100} of HR-CTV was 100% (50 Gy) by EBRT. The total physical and EQD_2 doses from HDR and combined (EBRT and HDR ICBT) EQD_2 doses for OARs are summarized in Table 3. The combined D_{2CC} mean dose for bladder, rectum and sigmoid colon were found to be 68.89 Gy (S.D.: ± 8.76), 63.74 Gy (S.D.: ± 3.82) and 73.20 Gy (S.D.: ± 3.04) respectively. For sigmoid colon, in 3 patients out of 13 the combined (EBRT and HDR) EQD_2 dose for D_{2CC} were exceeded the tolerance limit dose of 75 Gy. While the combined (EBRT and HDR) EQD_2 dose for D_{2CC}in all 13 patients were within tolerance limit for bladder and rectum.

The total physical and EQD_2 doses from HDR and combined (EBRT and HDR ICBT) EQD_2 doses for target are summarized in Table 4. The combined mean dose for dosimetric parameters HR-CTV D_{90}, HR-CTV D_{100} and average point 'A' were found to be 100.82 Gy (S.D.: ± 6.08), 70.95 Gy (S.D.: ± 2.76) and 79.46 Gy (S.D.: ± 0.66) respectively.

Discussion

Conventionally, ICBT treatment planning was based on 2D orthogonal X-ray film using ICRU 38 [8] recommendations, which permit the calculation of point doses like point 'A', point 'B' and ICRU bladder and rectum reference points. Orthogonal X-ray film yield spatial information of applicator with respect to bony structure. Yet, point doses are not true implications of maximum doses of critical structures.

Patient No.	HR-CTV D_{90} (%)			HR-CTV D_{100} (%)			Average Point 'A' Dose (%)		
	1st #	2nd #	3rd #	1st #	2nd #	3rd #	1st #	2nd #	3rd #
1	146.95	146.72	170.70	80.95	79.39	111.15	100.24	97.71	101.07
2	128.18	128.36	123.13	74.41	73.16	65.38	94.48	101.55	101.06
3	122.74	155.00	171.00	68.49	81.26	96.20	96.59	99.79	97.46
4	129.61	119.63	143.63	71.30	62.27	73.72	99.05	97.77	95.84
5	128.63	150.11	155.90	61.33	67.56	90.60	100.96	102.05	101.02
6	158.32	154.67	162.88	98.38	70.36	93.40	100.04	100.29	101.13
7	150.76	144.92	156.44	76.90	82.19	83.13	96.71	99.80	102.14
8	132.99	133.01	128.54	72.85	61.33	77.21	101.89	93.60	99.85
9	157.10	152.20	149.68	88.11	81.26	71.61	100.74	99.49	100.71
10	143.30	130.80	130.69	77.52	71.30	70.05	100.88	100.20	101.02
11	134.24	126.61	126.02	78.46	60.40	72.54	97.89	92.21	97.98
12	145.18	143.64	172.65	80.01	84.68	89.66	96.86	100.89	101.64
13	150.74	150.74	154.35	62.89	63.51	84.68	101.27	101.35	101.06
Mean	140.67	141.26	149.66	76.28	72.21	83.03	99.05	98.88	100.15
S.D.	11.89	12.01	17.83	9.89	8.80	12.96	2.31	3.00	1.87

D_{90}=Dose received to 90% of HR-CTV, D_{100}=Dose received to 100% of HR-CTV, HR-CTV=High risk clinical target volume, 1st #=First fraction, 2nd #=Second fraction, 3rd #=Third fraction, S.D.=Standard deviation

Table 1: Dosimetric parameters D_{90} (%), D_{100} (%) and average point 'A' dose for target (HR-CTV) of individualized plans for all patients.

Patient No.	Bladder D_{2cc} (Gy)			Rectum D_{2cc} (Gy)			Sigmoid colon D_{2cc} (Gy)		
	1st #	2nd #	3rd #	1st #	2nd #	3rd #	1st #	2nd #	3rd #
1	4.08	4.55	6.71	4.41	5.28	4.75	5.37	5.60	5.13
2	3.35	5.49	5.34	3.59	3.63	4.10	5.59	5.10	4.79
3	6.92	6.23	6.46	3.84	5.03	4.54	5.64	5.33	5.50
4	3.41	3.49	3.71	3.55	3.68	3.98	5.60	6.12	6.33
5	3.99	3.63	3.68	3.38	5.00	4.25	5.35	5.16	5.20
6	4.82	4.72	5.13	4.54	4.62	4.48	5.41	5.11	5.34
7	3.31	3.58	3.72	3.03	4.00	4.07	5.59	4.44	6.14
8	3.39	2.86	2.90	3.56	3.80	3.65	5.40	5.56	4.98
9	5.45	5.69	5.85	4.17	4.52	4.07	5.34	5.58	4.76
10	7.04	4.33	4.99	2.98	3.72	3.57	4.16	4.75	4.31
11	3.03	4.41	3.49	3.05	3.04	3.34	6.20	5.57	5.61
12	6.54	6.66	6.23	4.62	4.22	4.56	5.62	5.52	5.42
13	5.23	5.24	4.89	5.19	5.20	4.84	5.53	5.53	5.06
Mean	4.66	4.68	4.85	3.84	4.29	4.17	5.45	5.34	5.27
S.D.	1.46	1.14	1.25	0.70	0.71	0.46	0.45	0.43	0.55

D_{2cc} =Dose received to 2 CC volume, CC=Cubic centimeter, OARs=Organs at risk, Gy=Gray, 1st #=First fraction, 2nd #=Second fraction, 3rd #=Third fraction, S.D.=Standard deviation

Table 2: Dosimetric parameters D_{2CC} for OARs of individualized plans for all patients.

Patient No.	Bladder D_{2cc} (Gy)			Rectum D_{2cc} (Gy)			Sigmoid colon D_{2cc} (Gy)		
	HDR	EQD_2	Total*	HDR	EQD_2	Total*	HDR	EQD_2	Total*
1	15.34	25.7	71.7	14.44	22.6	68.6	16.10	27.0	73.0
2	14.18	22.5	68.5	11.32	15.4	61.4	15.48	25.3	71.3
3	19.61	37.5	83.5	13.41	20.2	66.2	16.47	28.0	74.0
4	10.61	13.9	59.9	11.21	15.1	61.6	18.05	32.6	78.6
5	11.30	15.3	61.3	12.63	18.5	64.5	15.71	29.2	75.2
6	14.67	23.2	69.2	13.64	20.6	66.6	15.86	26.3	72.3
7	10.61	13.9	59.9	11.10	15.0	61.0	16.17	27.4	73.4
8	9.15	11.1	57.1	11.01	14.7	60.7	15.94	26.5	72.5
9	16.99	29.5	75.5	12.76	18.5	64.5	15.68	25.9	71.9
10	16.36	28.5	74.5	10.27	13.3	59.3	13.22	19.6	65.6
11	10.93	14.7	60.7	9.43	11.6	57.6	17.38	30.6	76.6
12	19.43	36.8	82.8	13.40	20.0	66.0	16.56	28.2	74.2
13	15.36	25.0	71.0	15.23	24.6	70.6	16.12	27.0	73.0
Mean	14.20	22.89	68.89	12.30	17.70	63.74	16.06	27.20	73.20
S.D.	3.44	8.76	8.76	1.72	3.85	3.82	1.11	3.04	3.04

OARs=Organs at risk, D_{2cc}=Dose received to 2 CC volume, CC=Cubic centimeter, Gy=Gray, HDR=High dose rate, EQD_2=Dose equivalent to 2 Gy per fraction, 1st #=First fraction, 2nd #=Second fraction, 3rd #=Third fraction, S.D.=Standard deviation, Total*=Total dose including external beam radiotherapy (46 Gy) and high dose rate brachytherapy

Table 3: Total doses received by OARs.

In recent few decades, there have been impressive progresses in brachytherapy planning for Ca-Cx due to tremendous advances in 3D imaging technology (CT and MRI). After inception of concept of image based brachytherapy [9-12], enhanced clinical outcomes have been reported by various studies [15-17]. The GEC-ESTRO [10,11] guidelines recommended that MRI should be used for contouring of target and OARs due to its supremacy of tissue discrimination over CT images [18]. Yet, MRI and MRI compatible applicators are not available for brachytherapy treatment in most of radiotherapy centers especially in developing countries. Tan LT, study reported that in UK, the number of centers providing CT or MRI image based brachytherapy for Ca-Cx has increased to 32 (71%) in 2011 as compared with 12 (26%) in 2008 [19]. An alternative guideline for contouring of target using CT image was proposed by Viswanathan [13].

Dimopoulos evaluated the relationship between DVH parameters and local tumor control in MRI image based brachytherapy for cervical cancer and concluded that the D_{90} (EQD_2) value for HR-CTV equal or greater than 87 Gy resulted excellent (greater than 95%) local control rates [15]. They also find out that the D_{90} and D_{100} parameters represent the increase in local control with dose delivered to HR-CTV. Yet, the D_{100} dose parameter for HR-CTV has somewhat practical limitation in efficiency for the individualized patient plan because the received dose dependent on target delineation. Due to steep dose gradient, small spikes in target contour produce larger fluctuations in D100 parameters [11]. The results of Dimopoulos study provide strong proof for reliability of D_{90} for HR-CTV [15]. In our study, the total mean D_{90} (EQD_2) value for HR-CTV was 100.82 Gy and it was higher than Dimopoulos finding. The ABS/GEC-ESTRO guidelines recommend total EQD_2 dose including EBRT and ICBT should be 80-90 Gy [9-12]. The results of current study for D_{90} dose parameters of HR-CTV are found in good agreement with ABS/GEC-ESTRO recommendations and Dimopoulos study.

Jamema have analyzed the ICRU point doses using orthogonal radiographs with D_{2CC} doses using CT images for bladder and rectum

Patient No.	HR-CTV D_{90} (Gy)			HR-CTV D_{100} (Gy)			Average point 'A' dose(Gy)		
	HDR	EQD_2	Total*	HDR	EQD_2	Total*	HDR	EQD_2	Total*
1	32.51	56.6	106.6	19.01	26.1	76.1	20.93	29.6	79.6
2	26.58	41.8	91.8	14.91	18.6	68.6	20.80	29.3	79.3
3	31.41	54.1	104.1	17.21	22.7	72.7	20.57	28.9	78.9
4	27.49	44.0	94.0	14.51	18.0	68.0	20.49	28.7	78.7
5	30.42	51.2	101.2	15.36	19.5	69.5	21.28	30.3	80.3
6	33.31	58.6	108.6	18.36	24.8	74.8	21.10	30.0	80.0
7	31.64	54.2	104.2	16.95	22.1	72.1	20.91	29.6	79.6
8	27.62	44.2	94.2	14.79	18.5	68.5	20.67	29.1	79.1
9	32.34	56.0	106.0	16.87	22.0	72.0	21.07	29.9	79.9
10	28.34	46.0	96.0	15.32	19.3	69.3	21.15	30.0	80.0
11	27.08	43.0	93.0	14.80	18.5	68.5	20.17	28.1	78.1
12	32.30	56.1	106.1	17.81	23.7	73.7	20.96	29.2	79.2
13	31.90	54.9	104.9	14.78	18.5	68.5	21.26	30.3	80.3
Mean	30.23	50.82	100.82	16.21	20.95	70.95	20.87	29.46	79.46
S.D.	2.42	6.08	6.08	1.56	2.76	2.76	0.33	0.66	0.66

HR-CTV=High risk clinical target volume, D_{90}=Dose received to 90% of HR-CTV, D_{100}=Dose received to 100% of HR-CTV, Gy=Gray, HDR=High dose rate, EQD_2=Dose equivalent to 2 Gy per fraction, 1st #=First fraction, 2nd #=Second fraction, 3rd #=Third fraction, S.D.=Standard deviation, Total*=Total dose including external beam radiotherapy (50 Gy in 25 fractions) and high dose rate brachytherapy

Table 4: Total doses received by target (HR-CTV and average point 'A').

in intracavitary brachytherapy planning [16]. The study demonstrated that the mean D_{2CC} doses for rectum and bladder were 1.11 and 1.56 times the ICRU point doses respectively and concluded that ICRU rectal point dose correlated well with maximum rectal dose, whilst bladder ICRU point dose underestimated the bladder dose. Madan R evaluated the dosimetric comparison of 2D radiography and 3D-CT image based brachytherapy planning for Ca-Cx and demonstrated that OARs doses were underestimated and target coverage was overestimated in 2D treatment planning [20]. The study by Hashim N compared the DVH and ICRU point doses of rectum and bladder in 3D treatment planning based on CT image for Ca-Cx and reported that OARs doses evaluated from DVH were higher than ICRU point doses [21].

Georg P study correlated the DVH parameters with late side effects of OARs (bladder, rectum and sigmoid colon) in MRI image guided brachytherapy for cervical cancer [16]. They reported that the parameters D_{2CC} and D_{1CC} were good predictive value for rectal toxicity, while DVH parameters were predictive alone when severe toxicity level for bladder was considered. Our study reported that the totals mean EQD_2 dose for rectum was 63.74 Gy (± 3.82 Gy) and it was below the tolerance limit of 75 Gy as per ABS, GEC-ESTRO and ICRU 89 recommendations. For bladder the totals mean EQD_2 dose was 68.89 Gy (± 8.76 Gy) reported, which was around 23.45% lower than tolerance limit of 90 Gy as per established guidelines recommendations.

Current study reported that totals mean EQD_2 dose for sigmoid colon was 73.20 Gy (3.04 Gy) and it was within the tolerance limit of 75 Gy. It was also found that total EQD_2 dose of three patients out of thirteen patients were higher than tolerance limit. George's [16] study demonstrated that no effect of DVH parameters on toxicity for sigmoid colon due to paucity of sufficient data. Hence, due to lack of sufficient clinical evidences relating sigmoid colon dose to toxicity, the target dose was not compromised in this study to reduce the sigmoid colon dose within tolerance limit.

The limitation of current study contains short sample size, lack of clinical follow up due to retrospective nature of study, use of metallic applicator and use of CT image for planning. The use of metallic applicators yields artifacts in CT images which creates difficulty in applicator reconstruction and also may lead inaccuracies in target and OARs delineation. Viswanathan study compared the target delineation on CT image with MRI image and demonstrated that width of CTV on CT image was larger than that of MRI image [13]. So the HR-CTV delineation on CT image in this analysis may result underestimate or overestimate the tumor volume. This may be the cause of higher HR-CTV D_{90} value in this study.

Conclusion

This dosimetric analysis suggests that 3D-CT image may be the moderate option of imaging for ICBT treatment planning of Ca-Cx for resource setting radiotherapy centers. The results of our study reported that dose volume parameters for target and OARs were found almost in agreement with recent established guidelines. In accordance, advanced imaging and recent established guidelines for dose prescription, calculation, recording and reporting, it is recommended that advanced image based brachytherapy planning should be performed for each fraction if possible.

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