Dosimetric comparison between ^{60}Co and ^{192}Ir High Dose Rate intracavitary brachytherapy in uterine cervical carcinoma: treatment planning study

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Abstract

Background:

In Thailand ^{60}Co and ^{192}Ir high dose rate (HDR) Intracavitary brachytherapy usually uses in combination with external beam radiotherapy for cervical carcinoma treatment. This research aimed to make a comparison of dose volume parameters between ^{60}Co and ^{192}Ir HDR intracavitary brachytherapy treatment planning in uterine cervical carcinoma. Methods: A sample of 24 cases was drawn from Ramathibodi Hospital, using simple random sampling method. A sample was selected from 12 cases of tandem and ovoids technique and 12 cases of cylindrical technique. In order to re-plan by having the same dwell position and optimization, the computed tomography (CT) images and patient's parameters from treatment planning were exported from ^{192}Ir source Oncentra Brachy v 4.3 TPS at Ramathibodi Hospital to ^{60}Co source HDR plus 3.0 TPS at Bhumibol Adulyadej Hospital. The mean differences of dose volume parameters and point doses from both plans were compared by using paired t-test analysis. Results: For tandem and ovoid technique, maximum difference for all dose volume parameters is less than 1.5%. For cylindrical technique, the maximum difference for all dose volume parameters of high-risk clinical target volume (HR-CTV) is 6.05%. , while the point dose differences at 0.5 and 1 cm from the tip of cylindrical applicator are statistically significant difference at 45.07% and 23.11%, respectively. Conclusion: Both ^{60}Co and ^{192}Ir source used for uterine cervical carcinoma treatment have no difference findings of dose volume parameters calculation in intracavitary brachytherapy treatment planning in tandem and ovoids. By contrast, cylindrical technique illustrates a statistically significance in mean difference especially for point doses from the applicator tip due to a different anisotropy function between two sources.

Introduction

Intracavitary brachytherapy usually uses in combination with external beam radiotherapy for cervical carcinoma treatment. ^{192}Ir radionuclide source is commonly used for HDR brachytherapy due to small size which become flexible for interstitial treatment. However, in the modern-day technology, ^{60}Co radionuclide source can be also created to be

the same geometrical dimensions as those of ^{192}Ir source. Moreover ^{60}Co source has longer half-life (5.27 years vs. 73.84 days), it brings down the cost due to less source changes if mechanical stability is maintained[1]. From previous research[1-3] the differences of radial dose functions and anisotropy functions between ^{60}Co source and ^{192}Ir source have been illustrated. For treatment planning system (TPS) that used TG-43U1 formalism, dose distribution in patient depends on the radial dose function and anisotropy functions for dose calculation of radioactive sources. Therefore the purpose of this study is to investigate the dosimetric comparison between ^{60}Co source and ^{192}Ir source in HDR intracavitary brachytherapy planning in uterine cervical carcinoma in terms of HR CTV, bladder and rectum volume and dose, and also dose at the tip of applicator, using 2 applicator techniques 1) tandem and ovoids and 2) cylindrical applicator.

Materials and methods

Radionuclide source data

^{60}Co and ^{192}Ir source data that use for dose calculation are different in radial dose function and anisotropy function due to difference in geometrical source sizes and energies. Model source of cobalt is new BEBIG ^{60}Co source (model Co0.A86) with capsule dimension of 1 mm diameter and 5 mm length, and source pellet dimension of 0.50 mm diameter and, 3.50 mm length[4]. The mean energy and half life of ^{60}Co are 1.25 MeV and 5.27 years, respectively. The iridium source model is Micro Selectron mHDR-v2r with capsule dimension of 0.90 mm diameter and, 4.55 mm length and source pellet dimension of 0.6 mm diameter and, 3.50 mm length [5]. The mean gamma energy and half-life of ^{192}Ir source is 0.375 MeV and 73.8 days, respectively.

Treatment planning system (TPS)

Treatment planning system (TPS) is a tool for calculating and demonstrating dose distribution in patients. TPS that used in this research belongs to 2 institutions. Oncentra Brachy v 4.3 for ^{192}Ir source calculation which is owned by Radiotherapy and Oncology Division, Ramathibodi Hospital. HDR plus 3.0 for ^{60}Co source calculation is installed at Bhumibol Adulyadej Hospital. Both TPS calculate radionuclide line source dose distribution using TG-43U1 formalism[1,6,7], it is a multiplication of air kerma strength (Sk), dose rate constant (Λ), relative geometry factor "G" ("r,θ")/" G" ("r" _"0" "," "θ" _"0"), radial dose function (g(r)), and 2D anisotropy function F(r,θ), as shown in equation (1).

$$\dot{D}(r,\theta)=S_k \Lambda \frac{G(r,\theta)}{G(r_0,\theta_0)} g(r) F(r,\theta) \quad (1)$$

C.Dosimetric volume parameters calculation

This study was retrospective approach. The patient data selected in the period of January 2015-May 2016 were anonymous and approved by IRB at Ramathibodi Hospital. The number of 12 cases were chose for ^{192}Ir patient treatment planning using tandem and ovoids applicator technique and the same number of cases for cylindrical technique treatment planning calculation. Regarding the tandem and ovoids applicator technique, the compared parameters were high risk CTV (which includes GTV, the whole cervix and extra-cervical tumor spread[8]) at volume of 100%, 150%, 200% and 400% dose and dose of high risk CTV of 90% and 100%volume. The dose parameters of bladder and rectum at volume of 0.1, 1, and 2 cc were also recorded. For the cylindrical applicator technique, point dose at distances of 0.5 and 1 cm from tip of the applicator were added to evaluate.

Once dose volume parameters calculated by ^{192}Ir planning were reported, CT images and structures files were imported from Oncentra ^{192}Ir Brachy v.3 TPS into HDR ^{60}Co plus 3.0 TPS. Patients were re-planned for ^{60}Co HDR source by using the same dwell position as those of ^{192}Ir. By making the same dose prescription, the dwell weight from ^{192}Ir planning were applied to the dwell time of ^{60}Co planning. The same parameters as those of ^{192}Ir source were recorded.

The percent dose and volume difference between ^{60}Co and ^{192}Ir planning were calculated. The pair t-test with p-value <0.05 was used to be termed "**statistically significant**" difference.

Results

From 12- patients sample group of tandem and ovoids technique in Table 1-2, the percent difference of the mean volume among HR-CTV at V100% to 400% between ^{192}Ir and ^{60}Co sources less than 1%. The result of percent difference of the mean dose among HR-CTV at D100% to 90% is less than 1% as well. The percent difference of mean dose of normal tissue at volume of 0.1 cc to 2 cc are less than 1% and 1.5% for bladder and rectum, respectively. There is no statistically significant difference for all parameter comparison of tandem and ovoid techniques between ^{192}Ir and ^{60}Co with p-value more than 0.05.

The result of dose volume parameter comparison between ^{192}Ir and ^{60}Co sources for cylindrical technique in 12 cases is depicted in Table 3-4.The maximum percent difference of the mean volume among HR-CTV at V100% to 400% is 4.97% and mean dose difference of HR-CTV at D100% to 90% are 6.05%. The maximum percent dose difference of bladder and rectum are found at 0.1 cc volume which are 12.74% and 7.56%, respectively. However there is still no statistically significant difference for all parameter comparison of cylindrical techniques between ^{192}Ir and ^{60}Co with p-value more than 0.05, except at bladder volume of 0.1 cc, the *p*-value is exactly equal to 0.05. In contrast, the comparison of %point dose from the tip of cylindrical applicator for 0.5 and 1 cm are 45.07% and 23.11%, respectively. The results illustrate that p-value is less than 0.05 which is statistically significant difference for point dose comparison in cylindrical technique.

As noted that no matter what dose, volume or point dose comparison of ^{60}Co source are higher than those of ^{192}Ir source.

Table 1. The volume parameters differences between ^{192}Ir and ^{60}Co brachytherapy planning from Tandem and ovoids technique.

Parameters	Ave. volume of ^{192}Ir(%)	Ave. volume of ^{60}Co(%)	%volume difference, (^{60}Co -^{192}Ir)	Standard deviation	P-value
HR CTV V100%	92.64	92.74	0.09	1.99	0.866
HR CTV V150%	63.42	63.57	0.15	5.21	0.923
HR CTV V200%	40.34	40.84	0.50	3.60	0.640
HR CTV V400%	10.18	10.34	0.16	1.00	0.579

Table 2. The dose parameters difference between ^{192}Ir and ^{60}Co brachytherapy planning from Tandem and ovoids technique.

Parameters	Ave. dose of ^{192}Ir(%)	Ave. dose of ^{60}Co(%)	%dose difference, (^{60}Co -^{192}Ir)	Standard deviation	*P*-value
HR CTV D100%	73.70	74.49	0.79	4.99	0.594
HR CTV D90%	111.05	110.99	0.06	5.67	0.974
Bladder D0.1cc	89.24	89.88	0.64	4.33	0.626
Bladder D1cc	76.18	76.52	0.34	4.86	0.811
Bladder D2cc	70.22	71.00	0.78	3.59	0.465
Rectum D0.1cc	93.54	94.74	1.20	5.87	0.495
Rectum D1cc	79.97	81.30	1.33	4.55	0.334
Rectum D2cc	73.95	74.68	0.73	4.22	0.565

Table 3. The volume parameters differences between ^{192}Ir and ^{60}Co brachytherapy planning from Cylindrical technique.

Parameters	Ave. volume of ^{192}Ir(%)	Ave. volume of ^{60}Co(%)	%volume difference, (^{60}Co -^{192}Ir)	Standard deviation	*P*-value
HR CTV V100%	93.17	94.33	1.16	6.34	0.538
HR CTV V150%	60.12	65.09	4.97	11.26	0.154
HR CTV V200%	38.84	42.37	3.53	7.92	0.151
HR CTV V400%	12.33	12.21	-0.12	3.36	0.904

Table 4. The dose parameters and point differences between ^{192}Ir and ^{60}Co brachytherapy planning from Cylindrical technique.

Parameters	Ave. dose of ^{192}Ir(%)	Ave. dose of ^{60}Co(%)	%dose difference, (^{60}Co -^{192}Ir)	Standard deviation	*P*-value
HR CTV D100%	72.97	73.59	0.62	10.10	0.836
HR CTV D90%	108.72	114.77	6.05	13.91	0.160
Bladder D0.1cc	94.54	107.28	12.74	20.07	0.050
Bladder D1cc	77.38	83.59	6.21	11.18	0.081
Bladder D2cc	70.33	74.77	4.44	9.67	0.140
Rectum D0.1cc	103.87	111.43	7.56	15.20	0.113
Rectum D1cc	85.83	91.05	5.22	12.84	0.187
Rectum D2cc	77.11	80.67	3.56	9.46	0.220
0.5 cm from tip of applicator	68.79	113.86	45.07	36.46	0.001
1 cm from tip of applicator	40.20	63.31	23.11	15.29	<0.001

Note: Vx% being defined as the volume exposed to a dose ≥x % of a volume of interest
Dx% being defined as the dose exposed to x% of a volume
Dxcc being as the dose exposed to volume of x cc
$p<0.05$ meaning as "statistically significant" difference

Discussion

The hypothesis of this study is that there are dosimetric and volumetric differences between 2 planning calculated by ^{192}Ir source data and ^{60}Co source data. From the results, it was found that the mean of %dose volume parameter differences between 2 treatment planning systems was not statistically significant different, except point dose at distance of 0.5 cm and 1 cm for cylindrical technique. The results of dose volume parameter comparison were inconsistent with the hypothesis. This is because the differences in the physical characteristics of ^{192}Ir source and ^{60}Co source are not so much to make a difference of mean of the dose volume parameters. The result is compliant with previous research. Palmer et al[2] reported that there was no significant difference in D90% between ^{192}Ir source and ^{60}Co source. Our work used tandem and ovoids techniques, and cylindrical techniques that are different from Palmer et al's study which used an intrauterine tube (IU) and a two-channel ring. However among 3 techniques provided the same result in D90%. In point dose from the applicator tip along the source axis (point dose at distance of 0.5 cm and 1 cm for cylindrical technique), there is a statistically significant difference because of the difference of anisotropy factor especially at the top of the ^{192}Ir source demonstrated in the report of Sromaier S et al[9]. This result also illustrated by Palmer et al. again which reported that there was a reduction in anisotropy function along the source axis of 40% at 2 cm from the source for ^{192}Ir compared to ^{60}Co.

Conclusion

There is no dose and volume parameters differences between ^{192}Ir and ^{60}Co sources treatment planning in intracavitary brachytherapy using tandem and ovoid technique. However less self absorption within the line of ^{60}Co compared with that of ^{192}Ir source, there is a statistically significant difference of point dose at 0.5 cm. and 1 cm. from applicator tip in the cylindrical technique.

Acknowledgements

The authors are grateful to Department of Radiology, Faculty of Medicine Ramathibodi Hospital and Radiology Department of Bhumibol Adulyadej Hospital for their valuable technical support and encouragement.

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