ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 12, pp.62673-62678, December, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

DOSIMETRIC COMPARISON BETWEEN 3-D CRT AND DYNAMIC IMRT IN THE TREATMENT OF CERVICAL CANCER

Deivanayagam, R. and Mohan, P.

Department of Radiotherapy, Tirunelveli Medical College Hospital, Tirunelveli -627011, Tamilnadu, India

ARTICLE INFO

Article History:
Received 22nd September, 2017
Received in revised form
17th October, 2017
Accepted 03rd November, 2017
Published online 27th December, 2017

Key words:
Dose homogeneity, Organ at risk,
Computed tomography,
Conformal radiotherapy,
Intensity modulated radiotherapy.

ABSTRACT

The purpose of this study was to investigate the potential advantage of Intensity Modulated Radiotherapy (IMRT) over 3-Dimensional conformal radiotherapy (3-D CRT) techniques for external-beam radiation treatment for cervical cancer. A comparison of two treatment techniques was performed using dose statistics, dose-volume histograms, homogeneity and conformity values. For IMRT plans the conformity value was closely to 1 and homogeneity value closer to 0 better than 3-D CRT. Our study indicates that the bowel volume irradiated to 45 Gy was 52.82 cc and 50 Gy was 13.45 cc for IMRT in comparison with 67.3 cc and 20.18 cc for 3-D CRT. The data shows that IMRT has the potential to greatly reduce small bowel acute toxicities when compared with 3DCRT. In conclusion IMRT has clinical advantages over 3-D CRT with improved PTV coverage and improved sparing of small bowel in the radiotherapy treatment of cervical cancer.

Citation: Deivanayagam, R. and Mohan, P. 2017. "Dosimetric comparison between 3-d crt and dynamic imrt in the treatment of cervical cancer", *International Journal of Current Research*, 9, (12), 62673-62678.

INTRODUCTION

Cancer of the cervix has been the most important cancer in women in India, over past two decades (Nandakumar, 2009). Due to early detection and technical advances in treatment the mortality rate has come down rapidly. Radiotherapy aims to cure or locally control disease while concurrently minimizing complications in normal tissue. External beam radiotherapy (EBRT) and High Dose Rate (HDR) Brachytherapy are the most common radiotherapy treatment used for cervical cancer. Depending upon the staging of the tumor the treatment modality varies. The goal of EBRT is to deliver a uniform dose of radiation to the tumor volume while sparing normal tissue as much as possible. To achieve this, new radiotherapy treatment planning procedures such as 3-D Conformal radiotherapy (3-D CRT) and Intensity Modulated Radiotherapy (IMRT) commonly used in EBRT techniques for the treatment of cancer cervix. According to International Commission for Radiation Units and measurements (ICRU, Report 62) the Gross Tumor Volume (GTV) is the palpable tumor and the Clinical Target Volume (CTV) is the GTV plus the microscopic tumor extension and the Planning Target Volume (PTV) is the GTV plus margins that take into account patient and organ movement as well as the inaccuracies in daily patient set up (International Commission on Radiation Units and Measurements, 1999). For cervical cancer the target delineation and treatment techniques of radiation dose delivery to the tumor remains complex. This is due to the large planned target volume and surrounding critical organs such as Bladder, Rectum, Small bowel, Ilium etc. CT Images with 3-D treatment planning software help in displaying the 3-D Dose distribution at different levels in the PTV. In 3-D CRT four field techniques is often used in the EBRT treatment of cancer cervix. The beam arrangement consists of a parallel opposed anterioposterior pair and a parallel opposed right and left lateral pair. This field arrangement is known as a "box" technique because of the box like shape of the high irradiation region. The treatment planning system having 3-D capabilities is used to optimize the dose distribution with minimal degree of dose inhomogeneity to the PTV. Several Institutions have reported the use of different techniques to improve the dose distribution within the PTV (Roeske, 2000 and Stein, 1997). IMRT is the newest technique being used to deliver a radiation dose conformal to the target while sparing critical uninvolved structures. IMRT differs from 3-D CRT treatment delivery technique because it allows for variance in the intensity of the radiation beam across the area targeted by radiation beam. It has the ability to provide sharp dose gradient at the junction of target volume and adjacent critical organs (Kataria, 2006). The small bowel is a radiosensitive organ and acute radiation enteritis occurs in most of the patients undergoing radiotherapy

Corresponding author:* **Mohan, P.
Department of Radiotherapy, Tirunelveli Medical College Hospital, Tirunelveli -627011, Tamilnadu, India

for gynecological malignancies. Severe acute toxicity reported to 16-39% patients treated with pre-operative radiotherapy (Baglan, 2002 and Emami, 1991). In addition late bowel toxicity (diarrhea, bowel stricture, perforation or hemorrhage) is frequently presenting within the first year after radiotherapy (Letschert, 1990). Clinical studies have suggested that increasing the dose volume of bowel (BV) irradiated is related to development of late toxicity. Hence we have taken the small bowel only as Organ at risk (OAR) for our study. The purpose of this study was to compare the 3-D CRT and IMRT treatment planning techniques for the treatment of cervical cancer in terms of target volume dose homogeneity and conformity indices and dose to critical uninvolved structure small bowel. In this study nine patients of cervical cancers treated with 3-D CRT and retrospective study of the same patients with IMRT was carried out. We have described the planning methods used for 4-Field 3-D CRT and IMRT plans and show the comparison by furnishing the dose statistics and DVH results of all the cases.

MATERIALS AND METHODS

Nine patients with histologically proven sqamous cell carcinoma of cervix with same stage II (T_2 N_0M_0) were selected for this study. T_2 signifies cervical carcinoma invades beyond uterus but not to pelvic wall or to lower third of vagina, N_0 signifies no regional lymph node metastasis and M_0 signifies no distant metastasis (American Cancer Society, 2009). The treatment plan for 3-D CRT and IMRT were based on the CT images. The CT images of 3 mm thickness at different transverse section were taken to create 3-D image. 4-Field 3-D CRT was done for all the patients using 3-D forward planning. The appropriate wedges were used to obtain uniform dose distribution in the target volume.

Table 1. Plan objective for PTV

PTV(50.4 Gy)	
Volume %	Dose
>99	>90%(45.36 Gy)
>95	>95%(47.88 Gy)
<5	105%(52.9 Gy)
<1	107%(53.9 Gy)

Table 2. Plan objective for OAR (Small bowel)

Dose (Gy)	Maximal Volume(cm^3)
50	17
45	78

Table 3. Dose Statistics for PTV

Dose	3-D CRT (Mean±SD)	IMRT (Mean±SD)
Mean Dose(Gy)	51.38±1.61	52.57±1.85
Minimum Dose(Gy)	49.23±1.66	49.24±2.94
Maximum Dose(Gy)	54.91±20.05	53.85±19.2
V95- Volume receiving 95% of Dose	96±3.05	97±5.42
CI	0.964±0.03	0.971±0.054
HI	0.116±0.028	0.096±0.060

The organ at risk considered were small bowel, right and left Ilium femoral heads etc but only small bowel was analyzed. 3-D Radiation treatment planning system (RTPS) Eclipse (version 6.5 Varian, USA) with inverse planning software was used. High energy Linear Accelerator CLINAC IX (Varian, USA) Energy 6MV and 15 MV with 120 leaf millennium MLC was used for the treatment. Same Nine patients planned and treated with four fields 3-D CRT was taken up for the retrospective study by re-planning with dynamic IMRT technique. IMRT plans were created on the same CT images of nine patients taken up for the study. Seven fields of 6 MV Energy with different gantry angles were used. Inverse planning is used to obtain PTV coverage of 95% dose to 95% PTV volume with possible minimum dose to critical organs. For all cases the total doses were ranges from 5040 cGy to 5510.2 cGy.

Comparison Parameters

To compare the treatment techniques between 4-field 3-D CRT and dynamic IMRT, isodose distribution, dose statistics and dose volume histograms (DVHs) were calculated. The DVHs were displayed in terms of relative dose (%) and ratio of total structure volume. The DVHs were very useful parameters to compare treatment techniques (Niemierko, 1994). The DVHs indicate what fraction of volume of regions of interest receives radiation doses above the specified values. To determine the dose statistics maximum and minimum doses for the critical structure was obtained. The mean dose and standard deviation were also determined. The plan objectives for PTV and OAR are given in the Tables 1 and 2 respectively (Gallagher, 1986). The conformity index (CI) was calculated using the following formula

CI=Volume of PTV covered by reference

Dose/Volume of PTV

The value of CI varies between 0 and 1 and the value close to 1 gives better conformity of dose to the PTV. The Homogeneity Index (HI) which was defined by Nutting et al (Nutting, 2001) and Pezner et al (Pezner, 2006) as the difference in PTV dose D1 and D99 divided by the prescription dose was calculated. Small HI corresponds to more homogeneous dose distribution in PTV.

Table 4. Dose Statistics for OAR

Volume of OAR	3-D CRT (Mean±SD)	IMRT (Mean±SD)
V40 - % of Volume receiving 40%of prescribed dose)	70±11.4	61±16.4
V50 - % of Volume receiving 50%of prescribed dose)	63±9.4	41±17.8
V60 - % of Volume receiving 60%of prescribed dose)	27±18.3	27±18
V70 - % of Volume receiving 70%of prescribed dose)	15±14.1	16±15.3
V80- % of Volume receiving 80%of prescribed dose)	12±13.0	9±12.4
V90 - % of Volume receiving 90%of prescribed dose)	9±11.9	6±9.6
V95- % of Volume receiving 95%of prescribed dose)	5±9.8	2±3.5

Table 5. Dose Constraints and Small Bowel volume

Dose constraints	Small Bowel Volume in cc	
	3-D CRT	IMRT
50 Gy	20	13
45 Gy	67	54

RESULTS

The typical dose distribution produced by both 3-D CRT and dynamic IMRT on an axial slice of a patient are shown in

Figure 1 and Figure 2. The plan comparison DVH curves for PTV and OARs of the same patient are shown in Figure 3 and Figure 4. The analyzed data of nine patients with the mean doses to the PTV for 3-D CRT and IMRT is shown in Table 3. In the case of OAR small bowel the analyzed data of nine patients for 3-D CRT and IMRT is shown in table 4. The patients in our study had a delineated Bowel Volume of 673± 245 cm^3 which put them at risk of having bowel volume irradiated.

V40 represents the percentage volume of small bowel receives 40% of the prescribed dose. Similarly V50, V60, V70, V80 ,V90 and V95 represents the percentage volume of small bowel receives 50%,60%,70%,80%,90%,95% of the prescribed dose. V40, V50, V60, V70, V80 and V90 are shown in graphs for 3-D CRT and IMRT comparison. The mean dose values were significantly reduced in IMRT when compared with 3-D CRT plan. Table 5 shows the dose constraints and OAR volume for both the techniques.

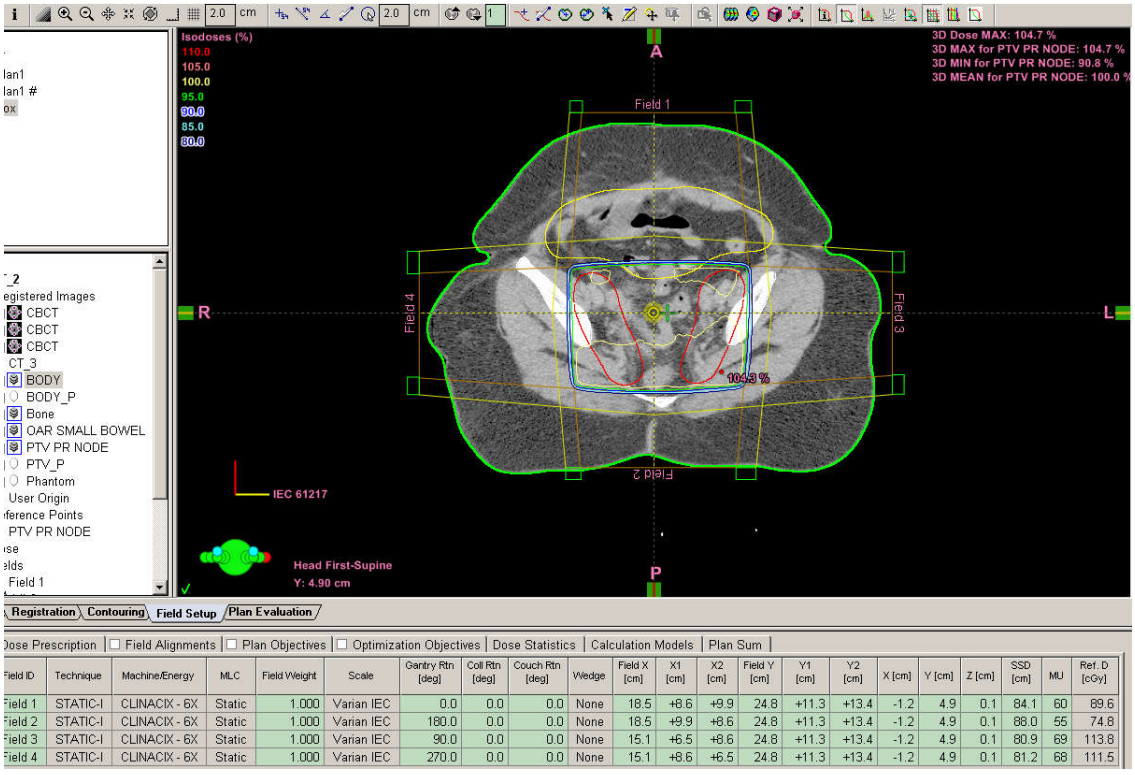


Figure 1. Isodose curves on an axial slice at isocentre plane of a representive patient for 3-D CRT plan

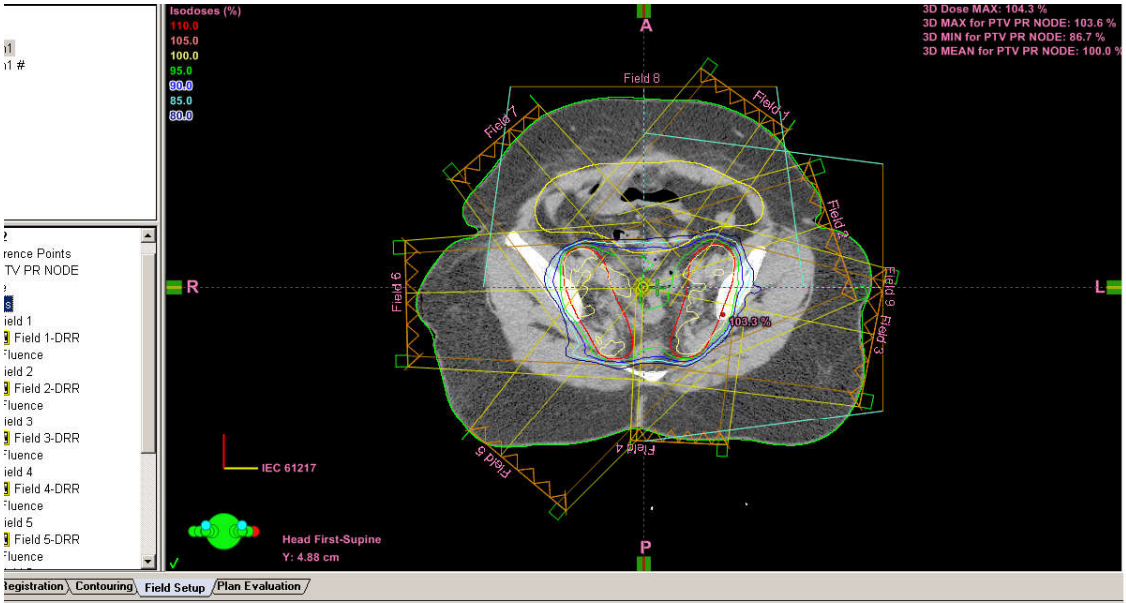
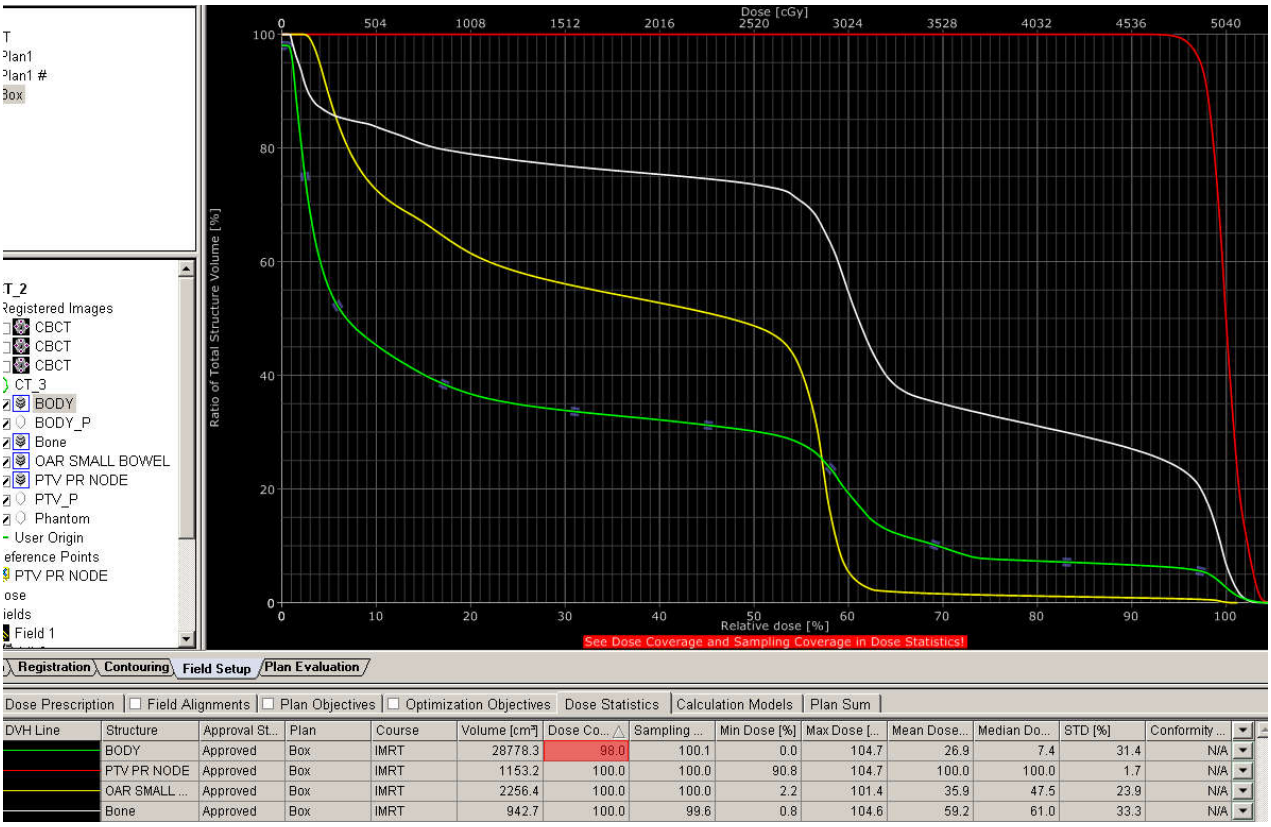


Figure 2. Isodose curves on an axial slice at isocentre plane of a representive patient for IMRT plan

D CRT Vs IMRT

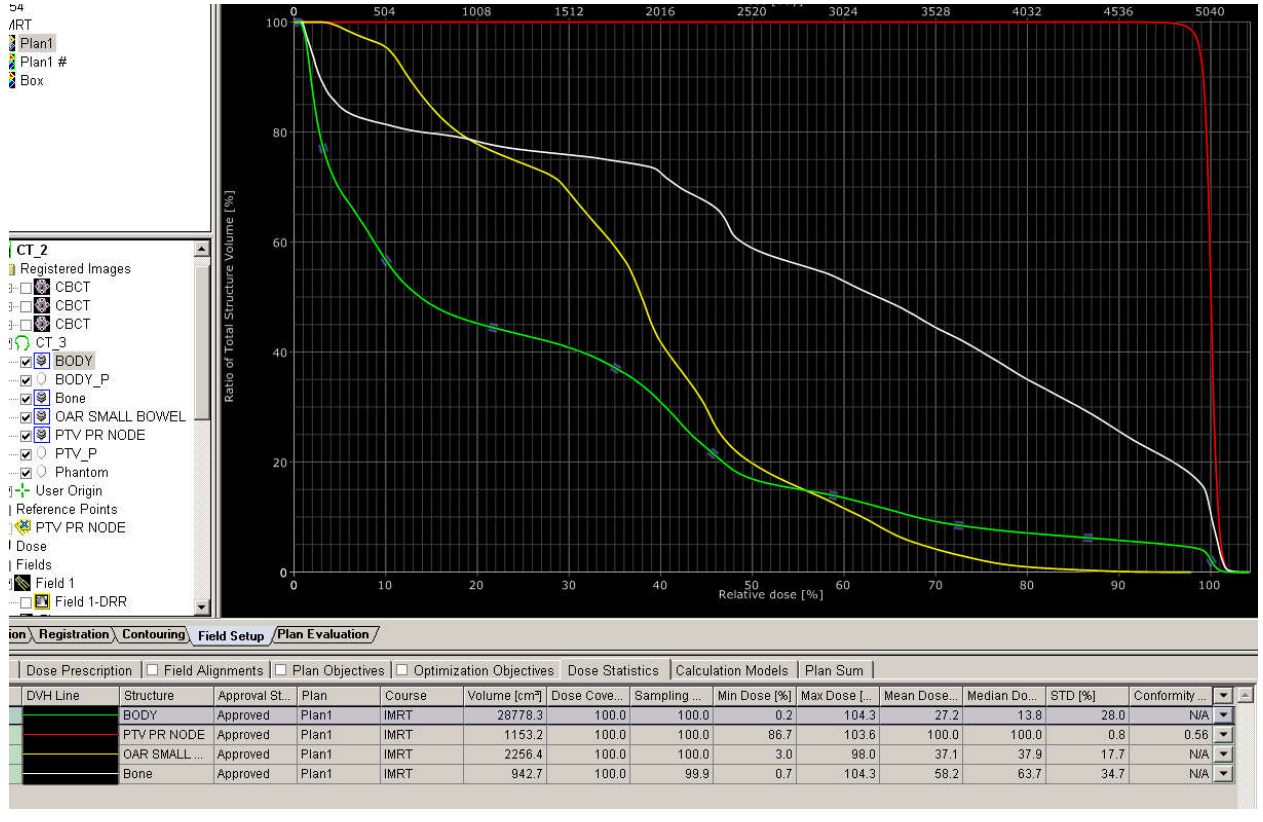
From table 3 it was observed that 3-D CRT and IMRT plans with V95>95% in all cases. IMRT plan had significantly lower maximal doses to the PTV compared with 3-D CRT plans. Further it was observed that V95% for IMRT plan increased slightly compared to 3-D CRT plans.

The variation between minimum and maximum dose is also reduced significantly in IMRT. The conformity value is also going closely to 1 for IMRT in comparison to 3-D CRT plan. The homogeneity index value is going closer to 0 for IMRT in comparison to 3-D CRT plans. Comparison of DVHs for both 3-D CRT and IMRT is shown in Figure 3 and Figure 4 and it



DVH Line	Structure	Approval St...	Plan	Course	Volume [cm³]	Dose Co...	Sampling ...	Min Dose [%]	Max Dose [...	Mean Dose...	Median Do...	STD [%]	Conformity ...
	BODY	Approved	Box	IMRT	28778.3	98.0	100.1	0.0	104.7	26.9	7.4	31.4	N/A
	PTV PR NODE	Approved	Box	IMRT	1153.2	100.0	100.0	90.8	104.7	100.0	100.0	1.7	N/A
	OAR SMALL ...	Approved	Box	IMRT	2256.4	100.0	100.0	2.2	101.4	35.9	47.5	23.9	N/A
	Bone	Approved	Box	IMRT	942.7	100.0	99.6	0.8	104.6	59.2	61.0	33.3	N/A

Figure 3. DVH curves of 3-D CRT plans of a representive patient for PTV and OAR



DVH Line	Structure	Approval St...	Plan	Course	Volume [cm³]	Dose Cove...	Sampling ...	Min Dose [%]	Max Dose [...	Mean Dose...	Median Do...	STD [%]	Conformity ...
	BODY	Approved	Plan1	IMRT	28778.3	100.0	100.0	0.2	104.3	27.2	13.8	28.0	N/A
	PTV PR NODE	Approved	Plan1	IMRT	1153.2	100.0	100.0	86.7	103.6	100.0	100.0	0.8	0.56
	OAR SMALL ...	Approved	Plan1	IMRT	2256.4	100.0	100.0	3.0	98.0	37.1	37.9	17.7	N/A
	Bone	Approved	Plan1	IMRT	942.7	100.0	99.9	0.7	104.3	58.2	63.7	34.7	N/A

Figure 4. DVH curves of 3-D CRT plans of a representive patient for PTV and OAR

was observed that % of volume of PTV receiving maximum % of dose is higher in IMRT than 3-D CRT.

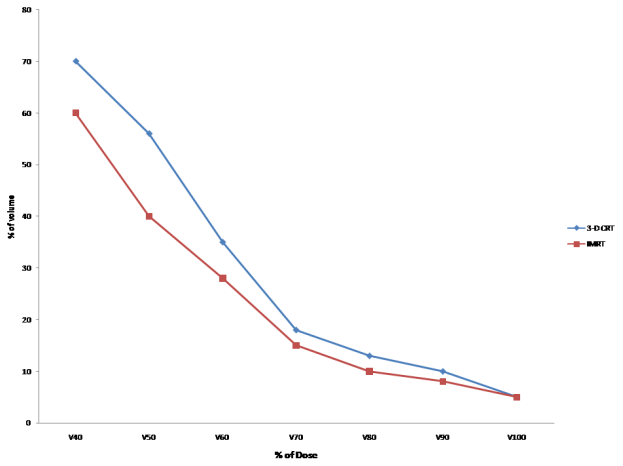


Figure 5. Comparison of DVH curves of small bowel for 3-D CRT and IMRT plans

DISCUSSION

The results of our study shown that the use of IMRT technique in cervical cancer patients was associated with 66% and 78% reduction in the BV irradiated to 45Gy and 50 Gy respectively compared to 3-D CRT technique. Several authors have suggested that the incident of late bowel toxicity is related to the BV irradiated (Capirci, 2001 and Minsky, 1995). Gallagher et al (Gallagher, 1986), reported no late toxicity when the BV irradiated to 45 Gy was <78 cm^3 and 50 Gy was <17 cm^3. Our study indicates that the BV irradiated to 45 Gy was 52.82 cc and 50 Gy was 13.45 cc for IMRT in comparison with 67.3 cc and 20.18 cc for 3-D CRT. This suggests the potential clinical benefit with IMRT techniques. We have also observed that IMRT delivers the prescribed dose to target volume (PTV) with excellent target coverage and conformity.

It has been suggested that a reduction in target homogeneity is the price to pay for increased conformity (Mundt, 2002). For IMRT plans the conformity value going closely to 1 and the homogeneity going closer to 0 and better than 3-D CRT plan. From Figure 5 it was observed that In IMRT technique a lower dose is usually spread over a large volume of normal tissue. In our study we found that % of volume of small bowel 50% of prescribed dose was less with IMRT in comparison to 3-DCRT. The DVH curves for bowel with IMRT and 3-D CRT are different at V40 (%), V50 (%), V80 (%) and V90 (%) levels. Therefore with IMRT sparing of bowel at higher dose levels may have potentially beneficial effect. The first report of clinical use of IMRT in gynecological tumors by Heron et al (Heron, 2003). and Mundt et al (Mundt, 2001) and confirmed the significant reduction of acute bowel toxicity (53.4%) when compared with 96% observed in conventional pelvic RT. In our study we have also found that for the treatment of cervical cancers the IMRT technique provides better homogeneity index value, conformity index value and sparing of small bowel in comparison with 3-D CRT technique.

CONCLUSION

Clear evidence from published reports has shown that irradiation of large volume of bowel was associated with increased acute and late toxicity (Letschert,1994). Our study has shown that IMRT techniques can reduce the bowel volume treated to higher dose levels while maintaining the PTV coverage. IMRT also provides the greatest amount of conformity in delivering radiation dose to the PTV and sparing doses to organ at risk such as small bowel compared with 3-D CRT. Although the 3-D CRT delivers a uniform, homogeneous dose to the tumor, the doses to the OAR is reduced with IMRT plans. This is due to sharp dose gradient at the junction between target and adjacent OAR and also more number of fields with appropriate gantry angle selection. An important point in considering IMRT was that a lower dose has been spread over a large volume of normal tissue. The DVH curve for 3-D CRT and IMRT are different at lower dose values 15-20 Gy. In conclusion this study suggests dosimetric advantages of IMRT over 3-D CRT in the treatment of cervical cancers. The advantages include improved PTV coverage and improved sparing of small bowel.

REFERENCES

American Joint Committee on cancer Cervix Uteri Cancer Staging 7 th Edition, American Cancer Society 2009.

Baglan, K.L., Frazier, R.C., Yan, D., et al. 2002. The dose-volume relationship of acute small bowel toxicity from concurrent 5-FU-based chemotherapy and radiation therapy for rectal cancer. int *J Radiat Oncol Biol Phys.,* 52:176-183.

Capirci, C., Polico, C., Mandoliti, G. 2001. Dislocation of small bowel volume within box pelvic treatment fields, using new "up down table" device. *Int J Radiat Oncol Biol Phys.*, 51:465-473.

Emami, B., Lyman, J., Brown, A., et al. 1991. Tolerance of normal tissue to therapeutic irradiation. *Int J Radiat Oncol Biol Phys.*, 21:109-122.

Gallagher, M.J., Brereton, H.D., Rostock, R.A., etal. A prospective study of treatment techniques to minimize the volume of pelvic small bowel with reduction of acute and late effects associated with pelvic irradiation. *Int J Radiat Oncol Biol Phys., 1*2:1565-1573.

Heron, D.E., Gerszten, K., Selvaraj, R.N., King, G.C., Sonnik, D., Gallion, H., et al. 2003. Conventional 3D conformal versus intensity-modulated radiotherapy for the adjuvant treatment of gynecologic malignancies: a comparative dosimetric study of dose-volume histograms small star, filled. *Gynecol Oncol,* 91(1):39-45.

International Commission on Radiation Units and Measurements (ICRU) Report 62: Prescribing, recording and reporting Photon beam therapy (Supplement to ICRU Report 50). Bethesda: ICRU; 1999.

Kataria, T., Rawat, S., Sinha, S.N., et al. 2006. Intensity modulated radiotherapy in abdominal malignancies: our experience in reducing the dose to normal structures as compared to the gross tumor. *J Cancer Res Ther.*, 2(4):161-5.

Letschert, J.G., Lebesque, J.V., Aleman, B.M., et al. 1994. The volume / effect in radiation-related late small bowel complications: Results of a clinical study of the EORTC Radiotherapy Cooperative Group in patients treated for rectal carcinoma.. *Radiother Oncol.,* 32:l 16-123.

Letschert, J.G., Lebesque, J.V., de Boer, R.W., et al. 1990. Dose-volume correlation in radiation-related late small-bowel complications: A clinical study. *Radiother Oncol.* 18:307-320.

Minsky, B.D., Conti, J.A., Huang, Y., et al. 1995. Relationship of acute gastrointestinal toxicity and the volume of

irradiated small bowel in patients receiving combined modality therapy for rectal cancer. *J Clin Oncol.,* 13:1409-1416.

Mundt, A.J., Roeske, J.C., Lujan, A.E., et al. 2001. Initial clinical experience with intensity-modulated whole-pelvis radiation therapy in women with gynecologic malignancies. *Gynecol Oncol.,* 82:456-463.

Mundt, A.J., Roeske, J.C., Lujan, A.E. 2002. Intensity-modulated radiation therapy in gynecologic malignancies. *Med Dosim.,* 27: 13 1-136.

Nandakumar, A., Ramnath, T., et al. 2009. The magnitude of cancer cervix in India *Indian J Med Res*, 130. September pp 219-221.

Niemierko, A., Goitein, M. 1994. Dose-Volume distributions: a new approach to dose-volume histograms in three-dimensional treatment planning. *Med Phy,* 21:3-11.

Nutting, C.M., Bedford, I.L., Cosgrove, V.P., el al. 2001. A comparison of conformal and intensity-modulated techniques for oesophageal radiotherapy. *Radiother Oncol.* 61(2): 157-163.

Pezner, R.D., Liii, A., Han, C. el at. 2006. Dosimetric comparison of helical Tomotherapy treatment and step-and-shoot intensity-modulated radiotherapy of retroperitoneal sarcoma. *Radiother Oncol.,* 81(1):81-7.

Roeske, J.C., Lujan, A., Rotmensch, J. et al. 2000. Intensity Modulated whole pelvic radiation therapy in patients with gynecological malignancies. *Int J Radiat Oncol Biol Phys.* 48:1613-1621.

Stein, J., Mohan, R., Wang, X.H., et al. 1997. Number and orientations of beams in Intensity Modulated radiation treatments. *Med Phys.,* 24:149-160.

****