A comparative dosimetric study of neoadjuvant 3D conformal radiotherapy for operable rectal cancer patients versus conventional 2D radiotherapy in NCI-Cairo

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Key words: Dosimetric study in cancer rectum.

ISSN: 2070-254X

Abstract

Purpose : This study was to compare this multiple-field conformal technique to the AP–PA technique with respect to target volume coverage and dose to normal tissues .

Materials and methods: We conducted a single institutional prospective comparative dosemetric analysis of 22 patients who recieved neoadjuvant radiation therapy for rectal cancer presented to radiotherapy department in National Cancer Institute , Cairo in period between June 2010 to September 2011 using 3D conformal radiotherapy technique for each patient, a second radiotherapy treatment plan was done using an antroposterior (AP–PA) fields, the two techniques were then compared using dose volume histogram (DVH) analysis.

Results: Comparing different DVHs , it was found that the planning target volume (PTV) was adequately covered in both (3D & 2D) plans while it demonstrates that this multiple field conformal technique produces superior distribution compared to 2D technique, with considerable sparing of bladder, ovaries and head of both femora.

Conclusions: From the present study, it is recommended to use 3D planning for preoperative cases of cancer rectum so far it produces good coverage of the target as well as good sparing of the surrounding critical organs.

Introduction

Conventional 2 dimensional (2D) radiotherapy volume designs does not ensure customized conformal tumor treatment, and relies on bony landmarks identified on a kV simulator film to identify the anatomical location of the tumor

Innovative techniques using 3-D treatment planning are being investigated. ***[1]*** The most important contributions of 3-D treatment planning are the ability to plan and localize the target and normal tissues at all levels of the treatment volume, and to obtain dose-volume histogram data. A randomized trial of conformal versus conventional radiation therapy in 266 evaluable patients with pelvic malignancies has been reported by Tait and colleagues.***[2]*** Although there was a decrease in the volume of normal tissue volumes in the radiation field with conformal versus conventional treatment (689 cm3 versus 792 cm3), there was no difference in the level of symptoms or in medication prescribed. Meyerson and associates used a 3-D planned boost radiotherapy (0.9 Gy once or twice weekly to a total boost dose of 4.5 to 9 Gy) concurrently with pelvic irradiation (45 Gy/25 fractions).***[3]*** Dose-volume histogram information correlated with grade 3 and 4 toxicity, particularly with respect to small-bowel complications. The authors concluded that every effort should be made to limit the volume of small bowel receiving more then 40 Gy to less than 120 cc. Using a 3-D planning system, Koelbl and associates found that in patients receiving postoperative radiation, the use of the prone position plus a belly board decreased the small-bowel volume treated versus the supine position.***[4]*** An analysis of 3-D treatment planning techniques at the MGH suggests that the volume of small bowel in the radiation field is decreased with protons as compared with photons.***[5]***

To limit dose to previously irradiated critical structures, 3-D planning techniques are desirable for patients who undergo reirradiation. Although not well studied to date, the use of IMRT may further lower the dose to the critical structures while maintaining adequate doses in the planning target volume.***[6],[7]***

We sought to determine if the target conformity has improved when compared to 2D approaches and if this has been at the expense or benefit to surrounding OARS.

Patients & Methods

We conducted a single institutional prospective comparative dosemetric analysis of 22 patients (16 female patients & 6 male patients) who received neoadjuvant radiation therapy for rectal cancer that presented to radiotherapy department in National Cancer Institute , Cairo in period between June 2010 to September 2011, for each patient 2 different plans were designed 2D and 3D CRT.

Patients were simulated in the prone position and should have a full bladder. Radiopaque markers were placed to include anal, vaginal, and perineal skin , also the perineal scar should be wired. proper alignment of the patient position was done by using anterior and 2 lateral lasers, serial CT images with contrast were taken for every patient for proper identification of the internal iliac, presacral and perirectal nodal groups: the external iliac nodal region and surronding normal tissues which are considered organs at risk (OAR) including both femoral head and neck , bladder and metallically clipsed both ovaries .

For the 2D planning : patients were planned in the prone position with single posterior field and 2 lateral fields with or without anterior field according to the patient separation with the following borders.

For the posterior field:
Upper border: L5-S1.
Lower border: perineum.if the lesion is less than 6 cm from anal verge but higher lesions it is placed 3 cm below the palpable lesion .
Lateral border: 1.5-2 cm from the widest portion of pelvic brim.

For the lateral field:
Upper and lower: were the same like posterior field.
Anterior border : ½ of the symphysis pubis except in T4 cases where anterior border extends to include whole symphysis pubis.
Posterior border: cover the whole sacral piece.
Proper shielding for the soft tissue were done in the posterior and lateral fields.

For the 3D planning: A planning CT scan is performed with 3mm slices from the level of L5 to 2cm below the anal marker .
CT defined target volumes are based on the known patterns of local recurrence in rectal cancer.

The ***GTV*** includes all gross tumor seen on the planning CT scan with reference to information from diagnostic endoscopy, MRI and DRE. Any involved lymph nodes, extrarectal extension, or extranodal deposits seen on MRI should be included.

The ***CTV*** includes the primary tumor , mesorectum from the sacral promontory to insertion of levator ani into the rectal wall, and the posterior presacral space , the inferior pelvic subsite, including the anal perineum, anal sphincter, perianal and ischiorectal space, is included if the tumour is 6cm from the anal margin or if the tumor invades the anal sphincter. The mesorectal and lateral lymph nodes are included in all patients. The obturator nodes are included when the tumour is 10cm from the anal margin, and the external iliac lymph nodes included if there is anterior organ involvement.

It was generally agreed that the ***PTV*** is created by adding a margin of 1cm to 1.5cm to the CTV but ***in practice***, a margin may be added to the GTV to create the PTV directly ensuring the above CTV sites are included. The margins used to grow the GTV to PTV are 3–5cm superiorly (limited by the L5/S1 junction), 2cm to 3cm inferiorly, 2cm anteriorly, and posteriorly to cover the sacrum.
A radiation ***dose*** of 50.4 Gy was delivered in 28 fractions at 1.8 Gy per fraction, five days per week over five and half weeks

3D conformal CT planning allows for conformal shielding with MLC to normal tissues for dose reduction .

Dose volume histograms ***(DVH)*** were recorded for both femoral head and the bladder after they were contoured as organs at risk , oophropexy was done for 8 female patients of the studied group and both ovaries were marked by metallic clips and contoured and a DVH for each ovary was created .

Two DVHs were constructed for each of both femoral head and neck , bladder, marked both ovaries , CTV and PTV one for the conformal technique , and the other for an AP–PA technique . They were then exported from the Presice treatment planning computer system and averaged using Microsoft Excel to produce a 'mean' DVH for each organ or volume , the percentage volume receiving different doses was calculated and then averaged over the 22 patients to obtain a 'mean' value. These values were then plotted to produce a mean DVH.

Results

For each of the 22 patients (16 female patients & 6 male patients) 2 DVHs were constructed for the PTV, bladder , head of both femurs and both ovaries for female patients , one for the conformal technique and the other for the 2D technique , they were then exported for the precise treatment planning computer system and averaged using Microsoft Excel to "a mean" DVH for each organ or volume. The percentage volume receiving different doses was calculated and then averaged over the 22 patients to obtain a mean value. These values were then plotted to produce a mean DVH.

Radiation dose to the **bladder** is much lower in the 3D conformal radiotherapy planning ***fig. (1)*** , the average maximum dose received by the bladder in 2D planning was 53 Gy compared to 51 Gy for the 3D conformal planning , the average mean dose for 3D planning was 32 Gy versus 42 Gy for the 2D planning, also it was found that the V40 for the 2D plane was 73% compared to 50% for the 3D plane.

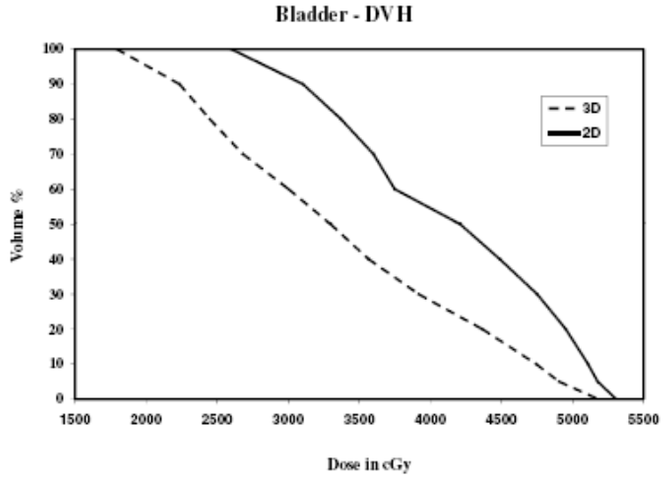

Fig 1: Mean DVH for bladder using 2D technique and 3D technique.

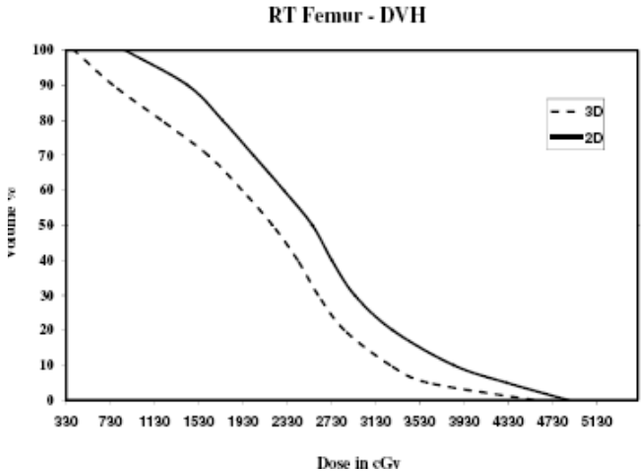

Fig 2: Mean DVH for right femur using 2D technique and 3D technique.

Figure (2) showed The average maximum dose received for the **head of right femur** is in favor for the 3D conformal planning 45 Gy compared to 48 Gy for the 2D planning. The mean average dose for the 3D planning was 21 Gy versus 25 Gy for the 2D planning , while for the **head of left femur** ***fig. (3)*** the mean average dose is in favor for 3D conformal planning 20 Gy compared to 27 Gy for the 2D technique , also it was found that the V50 in both the 2D and 3D planning was less than 10% and the dose at any point in both planes did not exceed 50 Gy .

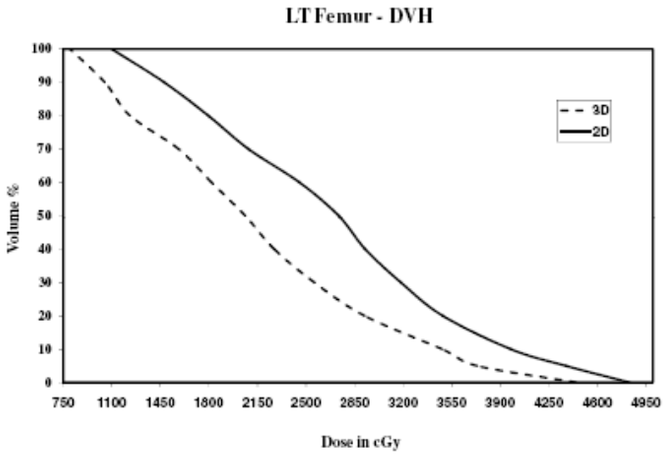

Fig 3: Mean DVH for left femur using 2D technique and 3D technique.

Oophropexy was done for 8 female patients of the studied group and both ovaries were marked by metallic clips and contoured and a DVH for each ovary was created , average radiation dose delivered to **right ovary** is much lower for the 3D conformal planning 5.54 Gy compared to 19 Gy in the 2D technique as shown in ***fig. (4)*** also it was found that the dose to 30% of the volume was 7 Gy for 3D plane versus 23 Gy for 2D plane and the dose to 60% of the volume was 4.9 Gy for 3D plane compared to17 Gy for 2D plane while the dose to 100% volume was 3 Gy for 3D plane versus 11.7 Gy for 2D plane , while in ***fig. (5)*** for the **left ovary** the mean average dose received by 3D planning was much lower compared to the 2D planning 11Gy versus 29 Gy , also it was found that the dose to 30% of the volume was 13.5 Gy for 3D plane versus 32 Gy for 2D plane and the dose to 60% of the volume was 10.5 Gy for 3D plane compared to 28 Gy for 2D plane while the dose to 100% volume was 8 Gy for 3D plane versus 13.6 Gy for 2D plane.

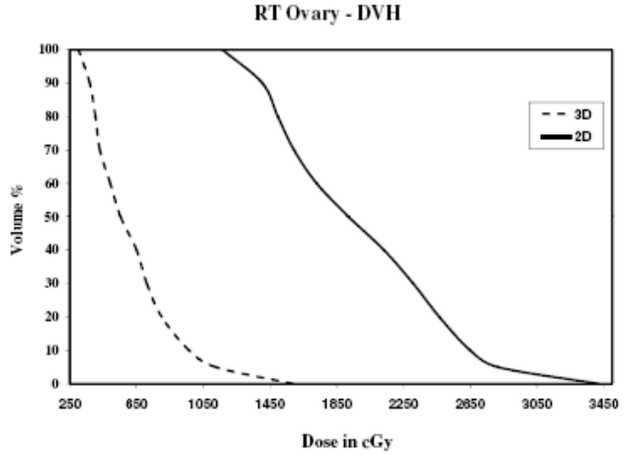

Fig 4: Mean DVH for right ovary using 2D technique and 3D technique.

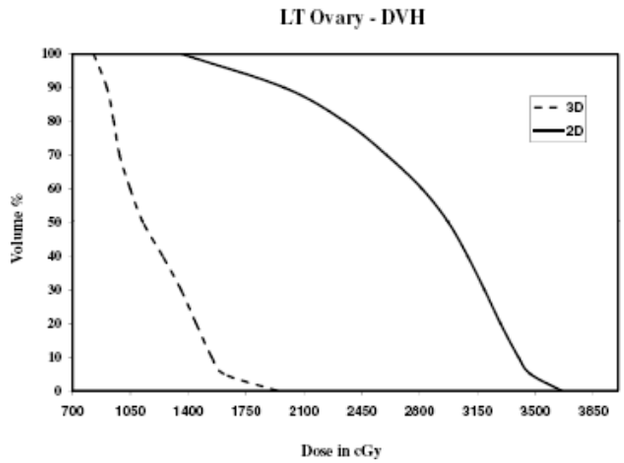

Fig 5: Mean DVH for left ovary using 2D technique and 3D technique.

Regarding the coverage of the **PTV** as shown in ***fig .(6)*** no difference was found between the 3D and 2D techniques where the average dose for the 50% PTV was about 51Gy , also it was found that the V99 was nearly the same that it was 90% for 3D plane and 91% for 2D plane .

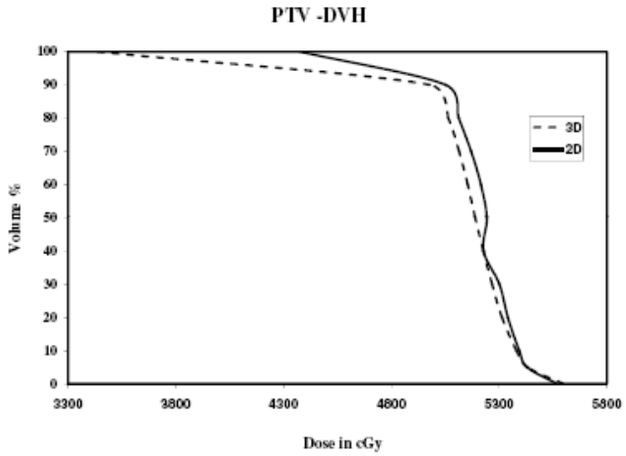

Fig 6: Mean DVH for PTV using 2D technique and 3D technique.

Discussion

Innovative techniques using 3D conformal treatment planning are being investigated. The most important contribution of 3D treatment planning was the ability to plan and localize the target and normal tissues at all levels of the treatment volume and to obtain dose volume histogram for both target volume and OARs.

Data based on the predominant locations of local recurrences and the frequency of lymph node involvement , Roels et al. ***[8]*** proposed guidelines for the definition and delineation of the clinical target volume (CTV) in rectal cancer which was the same data and steps used in the present study.

This study aims for dosimetric comparison between 2D and 3D planning of cancer rectum regarding the dose delivered to critical organs including bladder, ovaries and head of both femora as well as the dose delivered to PTV.

Our results demonstrates that this multiple field conformal technique produces superior distribution compared to 2D technique, with considerable sparing of bladder, ovaries and head of both femora.

These results were in concordance to the results achieved by Chen et al***. [9],*** Menkarios et al. ***[10]*** and Milano et al. ***[11]*** where radiation dose to the normal structures (particularly for femoral heads and bladder) were reduced when compared conventional 2D and 3D treatment planning.

Our study showed that the average radiation dose to the bladder is much lower in 3D conformal radiotherapy planning 32 Gy versus 42 Gy for the 2D plane, and the V40 for the 3D plane was 50% compared to 73% for the 2D plane which is going with what is stated in the QUANTEC REVIEW ***[12]*** that stated that the V65 should be less than 50%.

Regarding the radiation dose for both femoral heads the maximum radiation doses for the 3D conformal planning and 2D planning were 45 Gy and 50 Gy respectively. This is in concordance to Courteny et al.where the dose constrains of the femoral head was less than 50 Gy ***[13].***

Regarding to the dose delivered to 100% of right ovary in the 3D plan it was 3 Gy which is incocordance to the Emami et al . recommendations [14] while the dose delivered to 100% of left ovary in the 3D plan was much higher beyond the Emami et al. recommendations ***[14].***

Regarding the coverage of the PTV, no difference was found between the 3D and 2D techniques where the average dose for the 50% PTV was about 51Gy , also it was found that the V99 was nearly the same that it was 90% for 3D plane and 91% for 2D plane which is in concordance to that stated in Michael et al ***[15]*** .

Conclusions & Recommendations

From the present study, it is recommended to use 3D planning for preoperative cases of cancer rectum so far it produces good coverage of the target as well as good sparing of the surrounding critical organs.

References

1. Meyer J, Czito B, Yin FF, et al: Advanced radiation therapy technologies in the treatment of rectal and anal cancer: Intensity-modulated photon therapy and proton therapy. Clin Colorec Cancer 2007; 6:348-356.
2. Tait DM, Nahum AE, Meyer LC, et al: Acute toxicity in pelvic radiotherapy: a randomised trial of conformal versus conventional treatment. Radiother Oncol 1997; 42:121-136.
3. Myerson RJ, Valentini V, Birnbaum EH, et al: A phase I/II trial of three-dimensionally planned concurrent boost radiotherapy and protracted venous infusion of 5-FU chemotherapy for locally advanced rectal carcinoma. Int J Radiat Oncol Biol Phys 2001; 50:1299-1308.
4. Koelbl O, Vordermark D, Flentje M: The relationship between belly board position and patient anatomy and its influence on dose-volume histogram of small bowel for postoperative radiotherapy of rectal cancer. Radiother Oncol 2003; 67:345-349.
5. Tatsuzaki H, Urie MM, Willett CG: 3-D comparative study of proton vs. x-ray radiation therapy for rectal cancer. Int J Radiat Oncol Biol Phys 1991; 22:369-374.
6. Duthoy W, De Gersem W, Vergote K, et al: Clinical implementation of intensity-modulated arc therapy (IMAT) for rectal cancer. Int J Radiat Oncol Biol Phys 2004; 60:794-806.
7. Patel S, Vuong T, Ballivy O, et al: Phase II trial of pelvic intensity-modulated radiotherapy (IMRT) with concurrent chemotherapy for patients with rectal cancer. Int J Radiat Oncol Biol Phys 2004; 60:s424-s425.
8. Roels S, Duthoy W, Haustermans K, et al. Definition and delineation of the clinical target volume for rectal cancer. Int J Radiat Oncol Biol Phys 2006; 65:1129–42.
9. Chen YJ, Liu A, Tsai PT, et al. Organ sparing by conformal avoidance intensity-modulated radiation therapy for anal cancer: Dosimetric evaluation of coverage of pelvis and inguinal/femoral nodes. Int J Radiat Oncol Biol Phys 2005;63:274–281.
10. Menkarios C, Azria D, Laliberte B, et al. Optimal organ-sparing intensity-modulated radiation therapy (IMRT) regimen for the treatment of locally advanced anal canal carcinoma: A comparison of conventional and IMRT plans. Radiat Oncol 2007; 2:41.
11. Milano MT, Jani AB, Farrey KJ, et al. Intensity-modulated radiation therapy (IMRT) in the treatment of anal cancer: Toxicity and clinical outcome. Int J Radiat Oncol Biol Phys 2005;63: 354–361.
12. Lawrence B. Marks, M.D., Ellen D. Yorke, PH. D., Andrew Jackson, PH. D., et al. Use of normal tissue complication probability models in the clinic, Int. J. radiat Oncol, Biol. Phys. 2010 Vol. 76, No. 3, Supplement, pp. S10-S19.
13. Courtney R Buckey, Gregory P Swanson, Sotirios Stathakis et al. Optimizing prostate Intensity-Modulated Radiation Therapy (IMRT): Do Stricter Constrains Produce Better Dosimetric Results? EJCMO June 2010; 2:(2).
14. Emami, B., J. Lyman, A. Brown, L. Coia, M. Goitein, J. E. Munzenrider, B. Shank, L. J. Solin, and M. Wesson. Tolerance of normal tissue to therapeutic irradiation. Int J Radiat Oncol Biol Phys 1991;21:109–122.
15. Michael T. Milano, Louis S. Constine, Paul O. kunieff, Normal Tissue Tolerance Dose Metrics for Radiation Therapy of Major Organs , Seminars in Radiation Oncology, April 2007; vol .17, Issue 2, 131-140 .