Medical Dosimetry ▮ (2016) ▮▮▮–▮▮▮

Medical Dosimetry

journal homepage: www.meddos.org

The comparison of 5-field conformal radiotherapy techniques for the treatment of prostate cancer: The best for femoral head sparing

Mahkameh Zare, M.D.,[*] Marzieh Lashkari, M.D.,[†] Reza Ghalehtaki, M.D.,[†] Arash Ghasemi, M.D.,[‡] Hamidreza Dehghan Manshadi, M.D.,[*] Ali Mir, M.D.,[‡] Somayeh Noorollahi, B.Sc.,[*] and Mahboobeh Alamolhoda, B.Sc.[*]

[*]*Department of Radiation Oncology, Hafte-e-Tir Hospital, Iran University of Medical Sciences, Shar e Rey, Tehran, Iran;* [†]*Department of Radiation Oncology, Radiation Oncology Research Center, Cancer Institute, Tehran University of Medical Sciences, Tehran, Iran;* [‡]*Department of Radiation Oncology, Imam Khomeini Hospital, Sari University of Medical Science, Sari, Iran; and* [§]*Department of General Surgery, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran*

ARTICLE INFO

Article history:
Received 24 April 2016
Accepted 29 June 2016

Keywords:
Prostate cancer
Conformal radiotherapy
Dose-volume histogram
Optimization
Treatment planning

ABSTRACT

External radiotherapy is a standard treatment procedure for localized prostate cancer. Given the relatively high long term survival treatment complications have been brought in center of attention. In this planning study, between 2012 and 2014, CT simulation data of 90 consecutive high-risk prostate cancer patients were collected. In the first phase, all were planned for whole pelvis irradiation up to 46Gy in 23 daily fractions. In the second phase, only the prostate gland was the target of radiation. Next, the subjects were divided randomly into three groups and each received a unique 5field conformal radiation plan including Plan A (Gantry angle: 0, 60, 120, 240, and 300), Plan B (Gantry angles: 0, 90, 120, 240, and 270) and Plan C (Gantry angles: 0, 60, 90, 270, and 300). The total dose was 70Gy. For each patient, the rectum, bladder, and both femoral heads were contoured as the at risk organs (OAR). From dose volume histograms, the proportional dose of PTV V100, the bladder and rectum V80 and V90 and femoral head V50 and V100 were calculated in all subjects and compared across plans. A statistically significant difference in the femoral head V50 and V100 was found between our studied 5field plans so that in Plan A (beam angles: 0, 60, 120, 240 and 300) less dose was received by both heads of femur. This study suggests that 5 field treatment planning including an anterior, two anterior oblique and two posterior oblique portals to be more proper for 3D conformal radiotherapy in order to spare femoral head with acceptable PTV coverage, and bladder and rectal doses.

Introduction

In high-risk localized prostate adenocarcinoma, external radiation is a standard treatment leading to increased overall survival.[1] Despite astonishing advances in radiation techniques in recent years, normal tissue toxicity has remained an obstacle for dose escalations.[2] Needless to say, considering the radiobiological characteristics of prostate tumors, application of higher doses in the prostate gland may lead to better outcomes.[3] Newer techniques such as 3 dimensional conformal radiotherapy, intensity-modulated radiation therapy, or image-guided radiotherapy as compared with the conventional nonconformal radiotherapy allow radiation oncologists to prescribe higher doses while minimizing the doses received by normal surrounding organs.[4] However, some of these new technologies despite showing promising dosimetric benefits have yet to demonstrate improved patient outcome.[5,6] Thus, 3D conformal radiotherapy has remained a standard option for treating prostate cancer.

Regarding the relatively high survival rate in appropriately treated prostate cancer, normal tissue complications are of major importance.[7] Considerable bodies of evidences have clearly delineated the maximal tolerated dose of the pelvic organs under radiation. However, most of these studies were focused on the rectum, and fewer addressed the probability of bladder and pelvic bones complication.[8] Exploring the available literature, it seems that there is somewhat an uncertainty about the optimal safe dose and beam arrangement for femoral heads;

Reprint requests to Marzieh Lashkari, Department of Radiation Oncology, Radiation Oncology Research Center, Tehran Cancer Institute, Imam Khomeini Hospital Complex, Keshavaraz Blvd, Tehran, Iran.
E-mail: m-lashkari@sina.tums.ac.ir

http://dx.doi.org/10.1016/j.meddos.2016.06.008

however, there is a more established relationship between beam arrangement design, total prescribed dose, and the rate of complications in bladder and rectum, in particular.[9]

A pile of various field arrangements have been tested in earlier studies addressing the dose received by the normal pelvic organs during prostate cancer conformal radiation.[10] However, there is no consensus on any specific conformal radiotherapy plan with specific number of fields and a given dose that best covers the entire planning treatment volume (PTV) while least harming the normal structures within the true pelvis.

Thus, we tried to achieve a 3D conformal plan that, besides the full coverage of the PTV, is able to deliver the least amount of radiation to the normal organs around the prostate, particularly, the head of the femur bone.

Methods and Materials

Study design

In this planning study, computed tomography (CT) simulation data of 90 consecutive patients with high-risk prostate cancer (>15% risk of lymph node involvement) who were referred to the department of radiation oncology of the Hafte-e-Tir Hospital, Tehran, Iran, during 2012 to 2014 were collected. The risk stratification was defined based on the chance of lymph node involvement by Roach's equation [2/3 × prostate-specific antigen + ([Gleason-6] × 10)][11] that divides patients into low (<15% predicted and 6% actual risk) and high risk (>15% predicted and 40% actual risk). All patients were told to keep their bladder full at the time of the simulation CT imaging to spare the small bowel loops. Then they were positioned supine, and a knee rest was placed at popliteal areas of both legs. Finally, 5-mm-thick CT imaging slices were obtained from the umbilicus to the great trochanters.

CT imaging data were accessed in the workstation of our planning software for designing the treatment plan area. The total planned prescribed dose was 70 Gy in 35 daily fractions over 7 weeks of treatment. For each patient, the rectum, bladder, and both femoral heads were contoured separately as the at-risk organs.

In the first phase, all subjects were planned to receive whole pelvis irradiation from L5 to S1 junction superiorly to ischial tuberosity inferiorly, with 1-cm margin from pelvic rim laterally (4-field box plan with 18 MV), up to at least 46 Gy in 23 daily fractions.

In the second phase, only the prostate gland was contoured as clinical target volume (CTV). PTV was defined as the CTV plus a 10-mm margin for anterior, lateral aspects and a 6-mm posterior margin for rectal wall sparing. Next, the subjects were divided randomly into 3 equal groups, and each received a unique 5-field (beam) conformal radiation plan. Using the beam's eye view, all beam arrangements were visualized. Wedges and nonsymmetric collimation were used as needed. Only 18-MV energy x-rays were used. Finally, plan A included anterior, a pair of anterior oblique, and a pair of posterior oblique fields (Gantry angles: 0, 60, 120, 240, and 300). Plan B included anterior, opposed lateral parallel, and a pair of posterior oblique fields (Gantry angles: 0, 90, 120, 240, and 270). Plan C included anterior, a pair of anterior oblique, and opposed lateral parallel fields (Gantry angles: 0, 60, 90, 270, and 300).

After arranging the beams, the dose distribution was displayed in all the axial imaging sections, and 95% isodose lines were calculated. We made sure that all the PTV was covered by the 95% isodose surface in all CT cuts. Using dose-volume histograms, the mean PTV V_{100} values (the dose fraction received by 100% of the PTV), bladder and rectal V_{80} and V_{90} values (the fraction of total dose received by 80% and 90% of the bladder and rectum volume), and femoral head V_{50} and V_{100} values (the fraction of total dose received by 50% and 100% of the femur head volume) were evaluated and compared between different plans.

Statistical methods

All the data were treated as quantitative figures. We used the mean and standard deviation for description of the data. To compare the mean doses to PTV V100, rectal and vesical V80 and V90, and femoral head V50 and V100 among different plans, we used one-way analysis of variance test, and to further show the significant difference between each pair of plans, multiple comparison method was opted. The significance level for all of the statistical tests was considered as 0.05. We used SPSS software version 20 for all the analytical process.

Results

In this study, the mean dose and proportion of total dose received by different PTVs and at-risk organs were calculated among 30 subjects in each of 3 different 5-field conformal plan groups. As shown in Table 1, after comparing the means using one-way analysis of variance statistical test, there was no significant difference among the treatment plans in mean dose and proportion of total dose delivered to the PTV V_{100} and rectum and bladder V_{90} and V_{80}; however, we found a statistically significant difference among different plans in the femur head V_{50} and V_{100}. We performed multiple comparisons using post hoc tests to find the difference between each of the 2 groups when compared together. Post hoc tests revealed that the mean femoral head V_{50} was significantly lower in plan A *vs* plan B ($p = 0.002$) and plan C ($p = 0.000001$) whereas there was no difference between plans B *vs* C ($p = 0.164$). These tests again showed that mean femoral head V_{100} was significantly lower in plan A than plan C ($p = 0.011$), but there was no significant difference between plan A *vs* B or plan B *vs* C.

Figures 1 and 2 show the mean dose of femoral heads V_{50} and V_{100} based on the dose-volume histograms of the 3 compared plans.

Table 1
Dose-volume histogram analysis for PTV and at-risk organs according to % of total prescribed dose (70 Gy)

	Plan A (0, 60, 120, 240, and 300)		Plan B (0, 90, 120, 240, and 270)		Plan C (0, 60, 90, 270, and 300)		ANOVA
	Mean % of total dose (mean dose)	SD	Mean % of total dose (mean dose)	SD	Mean % of total dose (mean dose)	SD	*p* Value
Rectum							
V_{80}	79.15% (55.4)	10.92	75.55% (52.9)	10.85	75.33% (52.7)	10.31	0.305
V_{90}	64.56% (45.2)	17.10	62.16% (43.5)	16.03	62.09% (43.5)	15.71	0.800
Bladder							
V_{80}	79.61% (55.7)	14.13	79.18% (55.4)	13.71	78.96% (55.3)	14.07	0.983
V_{90}	72.44% (50.7)	16.65	71.69% (50.2)	16.31	71.84% (50.3)	16.87	0.983
Femoral head							
V_{50}	59.40% (41.6)	4.44	63.09% (44.2)	4.37	65.01% (45.5)	2.44	0.000
V_{100}	46.76% (32.7)	4.48	49.83% (34.9)	6.48	51.24% (35.9)	5.73	0.009
PTV							
V_{100}	92.09 (64.5)	2.94	92.80 (65.0)	2.74	92.30 (64.6)	2.00	0.558

ANOVA = analysis of variance; SD = standard deviation.