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Original Article

Comparison of Volumetric Modulated Arc Therapy and Fixed Field Intensity Modulated Radiotherapy for Radical Treatment of Early Prostate Cancer using Hypofractionated Radiotherapy

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ABSTRACT

Objective: To investigate the dosimetric advantages of volumetric modulated arc therapy over intensity-modulated radiation therapy for radical treatment of early-stage prostate cancer.

Study Design: Retrospective longitudinal study.

Place and Duration of Study: Department of Radiation Oncology, Combined Military Hospital, Rawalpindi Pakistan, from Jan to Jun 2019.

Methodology: Two treatment plans; one volumetric modulated arc therapy and other intensity-modulated radiation therapy, were made for 13 patients undergoing radical radiotherapy for early prostate cancer. Conformity index, Homogeneity index, the volume of rectum and bladder receiving a dose of 50 Gy or more, monitor units employed and treatment delivery time were compared between both techniques.

Results: Volumetric modulated arc therapy plans showed statistically better conformity index and Homogeneity index with significantly lower doses to the rectum and bladder than intensity-modulated radiation therapy plans. The number of monitor units (MUs) employed and treatment delivery time were also reduced significantly with volumetric modulated arc therapy.

Conclusion: Volumetric modulated arc therapy generates dose-metrically better radiotherapy plans than intensity-modulated radiation therapy and can deliver the required dose faster.

Keywords: Hypofractionated radiotherapy, Intensity-modulated radiation therapy, Prostate cancer, Volumetric modulated arc therapy.

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INTRODUCTION

Prostate cancer is the second-most frequently diagnosed cancer and the fifth leading cause of cancer death in males worldwide. Radical prostatectomy or radiotherapy are curative treatment options for early prostate cancer.[1] Owing to the lower risk of sexual dysfunction and urinary complications, radiotherapy has increased significantly over the last few years.[2] With the evolution of new three-dimensional conformal radiotherapy (3D-CRT) techniques, it became possible to deliver higher radiation safely,[3,4] 3D-CRT uses CT anatomy of the patient in the treatment position in treatment planning software, allowing higher doses of radiation to be delivered with a lower risk of side effects to neighbouring structures, especially the rectum, bladder, small bowel and femoral heads.[5] In fixed field intensity-modulated radiation therapy (IMRT), also called static or step and shoot IMRT, a multileaf collimator (MLC) shape radiation beam divides it in turn into multiple beamlets to deliver high dose radiation that conforms to the shape of the target volume and improves sparing of normal tissues and organs at risk (OAR).[6]

A CI value closer to 1 indicates that the volume of the prescribed dose more closely conforms to the PTV9. Dose homogeneity indicates the uniformity of dose distribution within the target volume.[7] The homogeneity index (HI) is calculated using the following formula-10. *D*2%, *D*98%, and *D*50% are the minimum received dose by 2%, 98%, and 50% of target volume. An HI value closer to 0 indicates a more homogeneous dose distribution within the PTV.[8] Doses for OARs are expressed as the volume of the organ receiving a particular dose; e.g. V50 of rectum means the percentage of rectum volume receiving a dose of 50 Gy or more.[9,10]

In this study, we aimed to investigate the dosimetric advantages of VMAT over step-and-shoot fixed field IMRT for radical treatment of early-stage prostate cancer undergoing radical radiotherapy with hypofractionated radiotherapy.

METHODOLOGY

The retrospective longitudinal study was conducted at the Department of Radiation Oncology,

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Combined Military Hospital, Rawalpindi Pakistan, from January to June 2019 after approval from the Institutional Review Board (Certificate No. 185/7/21).

Inclusion Criteria: Patients with biopsy-proven localized prostate cancer with stage T1 to T3a, N0 M0, undergoing radical radiotherapy, aged 60 to 80 years, with Eastern Cooperative Oncology Group (ECOG) Performance Status 0 or 1 were included in the study.

Exclusion Criteria: Patients with a history of prior pelvic radiotherapy, serum PSA >30 ng/ml, Gleason score of 9 or 10 on biopsy, and patients with metallic implants in the pelvis or femur were excluded from the study.

Thirteen patients were enrolled after obtaining informed written consent. CT simulation with a 1 mm slice thickness was performed for all patients supine with an empty rectum and a full bladder. CT data were fused with MRI for better delineation of target volumes. Two treatment plans (one for VMAT and Fixed field IMRT) were generated for each patient on Eclipse V13.5. Megavoltage X-ray beams of 6MV energy were used. Identical planning objectives were employed in generating both VMAT and IMRT plans. All VMAT plans employed a single arc, whereas IMRT plans used seven beams. The prescribed dose was 60 Gy in 20 fractions treated at three doses, i.e. 48 Gy, 57.6 Gy and 60 Gy, employing simultaneous integrated boost (SIB). CHHiP trial protocol was followed for contouring and dose prescription.[11] Conformity index (CI), Homogeneity index (HI), the volume of rectum and bladder receiving a dose of 50 Gy or more (V50), monitor units (MUs) employed, and treatment delivery time were compared between both techniques. Treatment delivery time was calculated in Quality Assurance (QA) mode and included gantry motion time.

Statistical Package for Social Sciences (SPSS) version 23.0 was used for the data analysis. Quantitative variables were expressed as Mean±SD and qualitative variables were expressed as frequency and percentages. Paired sample t-test compared treatment plan parameters. The *p*-value lower than or up to 0.05 was considered as significant.

RESULTS

All 13 pairs of VMAT and IMRT plans met the required planning objectives. Mean CI was 0.72±0.197 for VMAT and 0.54±0.047 for IMRT (*p*= 0.009). Mean HI was 0.09±0.028 for VMAT and 0.08±0.021 for IMRT (*p*=0.019). V50 of the rectum was 12.31±9.38% for VMAT and 15.54±10.465% for IMRT (*p*=0.001), whereas V50 for bladder was 15.19±9.149% in VMAT vs 17.60 ±10.37% in IMRT plans (*p*=0.003). The mean number of MUs employed for VMAT plans was 776.08±62.759 compared to 1077.69±128.516 in IMRT (*p*<0.001). The mean treatment delivery time in the case of VMAT was 108±5.5 seconds compared to 357±9.138 seconds in IMRT (*p*<0.001). The Table shows a comparison of various study parameters between VMAT and IMRT plans. Figure shows the target volume coverage in dose colour wash in VMAT and IMRT plans.

Table: Comparative Results of Various Parameters Between Volumetric Modulated Arc Therapy and Fixed Field Intensity Modulated Radiotherapy Groups (n=13)

Study Parameters	VMAT-Group (n=13)	IMRT-Group (n=13)	*p*-value
Conformity index (CI) (Mean±SD)	0.72±0.197	0.54±0.047	0.009
Homogenity index (HI) (Mean±SD)	0.09±0.028	0.08±0.021	0.019
V50 Rectum (Mean±SD)	12.31 ±9.38%	15.54±10.65	0.001
V50 Bladder (Mean±SD)	15.19±9.14%	17.60±10.7	0.003
Monitor units (MUs) (Mean±SD)	776.08±62.79	1077.69±128.516	<0.001
Treatment delivery Time (Mean±SD)	108±5.5 seconds	357±9.138 seconds	<0.001

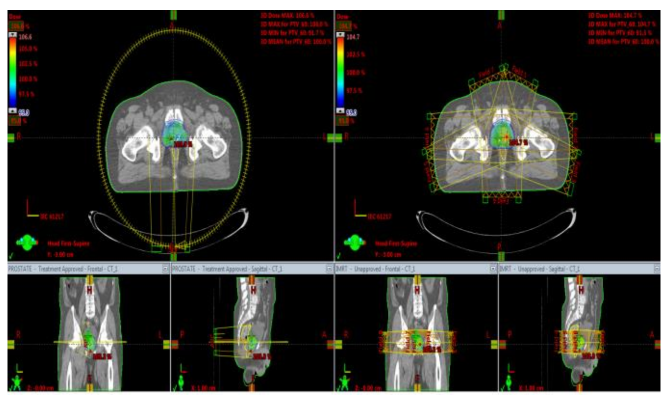

Figure: Image Illustrating a VMAT Plan (right) and an IMRT Plan (left) Showing 95% Dose Coverage in Dose Colour Wash for Treatment of Prostate Cancer(Total Prescribed Dose was 60 Gy in 20 Fractions)

DISCUSSION

Hypofractionated radiotherapy delivers a higher dose per fraction in fewer total fractions. Hypofractionated radiotherapy in early prostate cancer leads to the completion of radiotherapy in 20 days instead of 37-40 days. It is now endorsed by the American Society for Radiation Oncology (ASTRO), American Society for Clinical Oncology (ASCO) and American Urology Association (AUA).[11,12] This cost-effective approach reduces hospital stays and visits and allows radiation facilities to treat more patients simultaneously. On the other hand, using a higher dose per fraction could lead to increased toxicity of neighbouring OARs, especially bladder and rectum, in the case of prostate cancer. New radiation techniques of IMRT and VMAT have been used for over a decade. Both techniques have been compared in treating any tumours, and the superiority of one over the other is widely debated.[13,14]

In prostate cancer, most studies have compared dosimetric parameters of IMRT and VMAT plans with conventionally fractionated radiotherapy, i.e. 2 Gy per fraction. A meta-analysis by Ren *et al*. compared 110 plans of VMAT and IMRT for prostate cancer and found that VMAT plans had significantly reduced doses to the rectum with less Mus and treatment time compared to IMRT.[15] Our study has comparable results as far as rectal dose, MUs and treatment time are concerned. In contrast to our results regarding bladder dose, they found no significant difference in doses to the bladder with IMRT or VMAT. In a study conducted in Japan by Nguyen *et al,* there was statistically better CI and doses to OARs (rectum and bladder) in VMAT compared to IMRT plans. However, target dose homogeneity was statistically worse in VMAT plans.[16] In our study, both CI and HI are statistically better with VMAT.

We could find only one study in the literature comparing IMRT and VMAT for moderate hypofractionated prostate irradiation.[17] In this study by Abu-Hijlih *et a*l. conducted in Jordan, 4 out of 23 plans for IMRT could not meet the required planning parameters. VMAT plans were better than IMRT plans in CI, and HI, sparing OARs and employing fewer MUs, but the differences were not statistically significant.[17] Only the difference in treatment time was statistically significant. In contrast, the results of our study were significant in favour of VMAT for CI, HI, dose to OARs (rectum and bladder), MUs employed and treatment time. The reduced treatment time is convenient for patients, reduces potential intrafractional random errors, and improves the workflow of the radiotherapy setup.

Further studies prospectively comparing similar and other parameters are required to draw solid conclusions regarding the pros and cons of both planning techniques. The evolving role of stereotactic body radiotherapy using ultra hypofractionated radiotherapy may warrant comparison with existing techniques.[18]

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LIMITATIONS OF STUDY

The limitations of our study include the retrospective nature and potential confounding effects of factors like planning tools, patient's anatomy and physicist experience. Although all plans were made by the same physicist using similar planning parameters, their effect cannot be completely ruled out.

CONCLUSION

Volumetric modulated arc therapy generates dosemetrically better radiotherapy plans than intensity modulated radiation therapy and can deliver the required dose faster.

Conflict of Interest: None.

Authors Contribution

Following authors have made substantial contributions to the manuscript as under:

ZAA & SH: Conception, data acquisition, data analysis, drafting the manuscript, approval of the final version to be published.

MIKW & OR: Study design, drafting the manuscript, data interpretation, approval of the final version to be published.

TM & KK: Critical review, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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