IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 12, Issue 1 Ser. I (Jan. – Feb. 2020), PP 41-46
www.iosrjournals.org

Comprehensive Study between calculated and Measured DVHs for Prostate Cancer Patients Using IMRT/RapidArc Dosimetric Techniques

Ibrahim El Hamamsi[1], Khaled.M.Elshahat[2], A. EL-Shershaby[3], T.M.Hegazy[4]
[1](Medical Radiation Physicist, Faculty of Science,Tanta University, Egypt)
[2](Prof. of Medical Radiation Physics, Faculty of Medicine, Al Azhar University, Egypt)
[3](Prof. of Radiation Physics, Faculty of Women for Arts, Science and Education, Ain Shams University, Egypt)
[4](Prof. of Radiation Physics, Faculty of Women for Arts, Science and Education, Ain Shams University, Egypt)
Corresponding Author: Ibrahim El Hamamsi

Abstract: *The objectiveof this workis to compare betweenthe calculated dose by treatment planning system (TPS) and the measured dose collected by ArcCHECK phantom,for prostate cancer patients with two techniques:Volumetric Modulated Arc Therapy (VMAT) and Intensity Modulated Radiation Therapy (IMRT) using 3DVH system (Sun Nuclear Corporation, Melbourne, FL, USA). ArcCHECK is a 3D dosimetry quality assurance (QA)toolusedto measure the doses that are calculated by a (TPS)and compares them with the measured dose from the linear accelerator. The 3DVH is a measured dose(QA) software application used for comparing 3D dose and dose volume histograms (DVHs). One dataset is imported as a reference dose plan by(TPS), and the other is calculated by 3DVH from a correction of the intended TPS dose plan by ray tracing corrections that have been determined with a measurement system. 3DVH analysis uses the dose errors (derived from the measured versus calculated doses in phantom) to perturb the original 3D planned dose and accurately estimate the 3D dose distribution. This method that called PDP (Planned Dose Perturbation) results in fast, accurate, and powerful DVH comparisons.We evaluated dose difference between the TPS calculations and the collected dose reconstructed by 3DVH software.*

Keywords: *3DVH, QA, ArcCHECK, Gamma Pass Rate*

Date of Submission: 27-12-2019 Date of Acceptance: 11-01-2020

I. Introduction

In the familiar external beam radiation therapy (EBT), most treatments are delivered with radiation beams that are of uniform intensity across the field. Fashionable, wedges, compensators or MLCs are used to modify the beam profile to produce more uniform composite dose distributions. This process changes beam intensity to achieve the objective of a plan is called intensity modulation technique[1]. The characters (IMRT) refers to a radiation therapy technique in which non-uniform fluence is received by the patient from any directionof the treatment field to optimize the absorbed dose distribution[2].

The objective of IMRT is to treat a patient from many directions with fields of non-uniform fluences, which have been optimized to deliver a prescribed doseto the tumor volume (PTV) and minimize as low dose as possible to the surrounding normal structures (OARs).

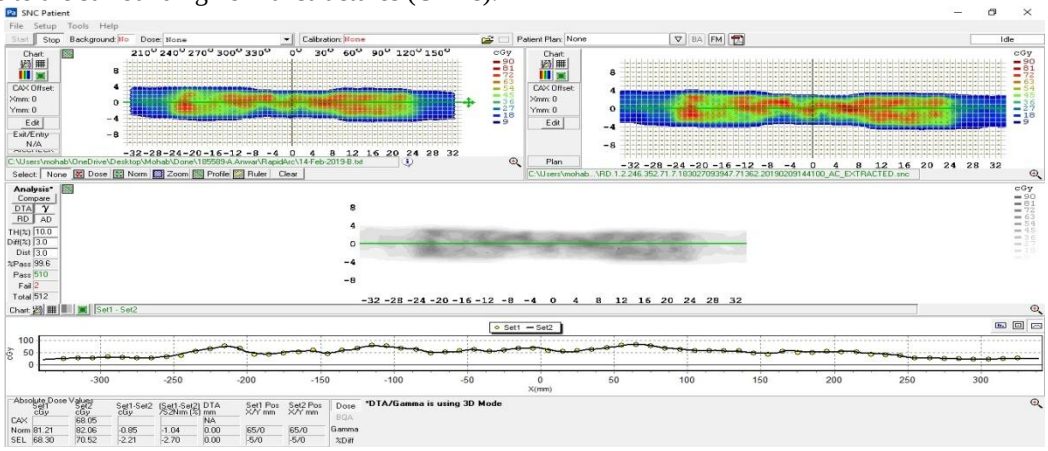

Fig 1: 2D dose analysis generated by SNC patient software shows measured ArcCHECK dose points

RapidArc or VMAT, which based on direct optimization of dMLC with Interdigitation, Gantry Speed and Dose Rate has more complex optimization than IMRT because it carries radiation from each angle around the patient[3]. The volumetric-modulated arc therapy (VMAT) technique, which depends on gantry rotation, can decrease the time and intrafractional errors. The treatment plans using the IMRT or RapidArc techniques are automatically established through an optimization process. Subsequently, these techniques are eligible to modulate the dose constraint of the PTV and normal tissue in the optimization process and this process reforms the PTV coverage and dose deliveredtoorgans at risk (OARs)[4]. VMAT integrates the interest of dose conformity and efficiency of dose delivery by treating with the highest regulation of beam orientations and reduces the time waste. VMAT technique promotes continuous alternation of dose rate, gantry speed, and MLCs position. Whilst the intensity of beam aperture is alternated continuously with dose rate and gantry speed varied. And then, it is recommended that the IMRT and RapidArc plans be validated before treatment because of the intricacy of the delivery beam. The goal of pretreatment verification is to confirm the state of treatment machine and the precision of optimized treatment plan[5][6].

The pretreatment dosimetric verification comprises a comparison of a measurement dose with (TPS)-calculated dose. In the past, the validation of treatment plans was executed out by using an ionizing chamber and a film dosimetry[7].

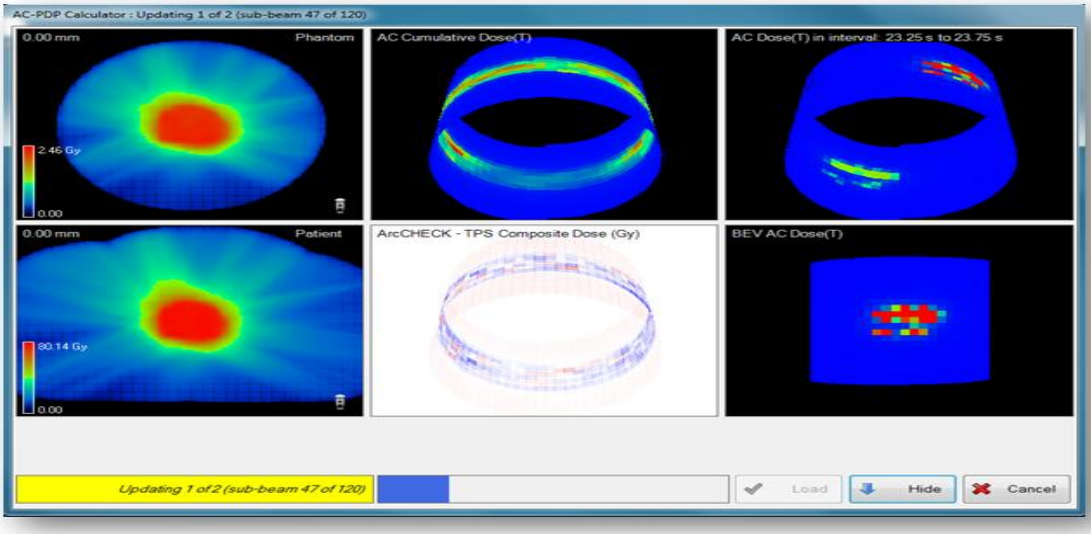

Figure 2: ArcCHECK Planned Dose Perturbation (ACPDP) calculation in 3DVH software (Sun nuclear)**.**

But, recently Sun Nuclear Corporation released a three-dimensional array such as ArcCHECK dosimetry systems which produced for pretreatment quality assurance (QA). ArcCHECK is water equivalent phantom, with a 3-dimensional array diode detectors designed to measurethecalculated dose that are collected, as defined by a TPS and compare this measurements with TPS dose [8]. When comparing the measured and the retroactive calculated dose in phantom, the gamma index (GI) that fuses the percentage dose difference (%DD) and the distance to agreement (DTA) is detected for each pixel. GI value>1 indicates that the measured absorbed dose agrees with the planned one within the passing criteria. The goodness of a treatment plan is thus determined through the assessment of the gamma passing rate (%GP), which represents the percentage of points that passed[9].

However, that device simply measure and evaluate the 2D dose distribution through gamma analysis; but the controversial issue at hand is to verify the dose for the tumor volume and health organs (OARs). Indeed there are several dosimetry systems that capable of estimation of patient dose based on QA measurement, such as the COMPASS system (IBA-Wellhofer, Germany), Dosimetry Check (Math Resolutions, Columbia), and 3DVH (Sun Nuclear Corporation, Florida). In this essay, we used the software program 3DVH with the ArcCHECK to scrutinize the correlation among %GP obtained during pretreatment QA tests. The signification of 3DVH software isloading beam measurements from a treatment plan and remodel 3-dimentional dose distribution within body structures for comparison with the calculated plan by TPS [10].

The 3DVH software uses conventional planar dose QA methods, such as MapCHECK, MapCHECK2, andEPIDose, to perform 3D patient dose and DVH (dose volume histogram) QA. 3DVH analysis uses the dose errors (derived from the measured versus calculated doses in phantom) to perturb the original 3D planned dose and accurately estimate the 3D patient dose. This patent-pending method that we call PDP (Planned Dose Perturbation) results in fast, accurate, and powerful DVH comparisons without introducing a new, error-prone

independent dose calculation engine[11]. The goal of this research is to evaluate the comparison between the 3DVH software and three dimensional pretreatment QA systems using two different dosimetry techniques.

II. Material and Method

Treatment plans were generated for 30 prostate cancer patients received 76 Gy with standard fractionation (2 Gy/fr) with VMAT and IMRT using Eclipse planning system V13.7.14 (Varian Medical System, Palo Alto, California). These plans were computed using photon beams of Clinac® iX System with energy 10 MV. IMRT plans were optimized for five fields (220^0 , 300^0 , 0^0 , 60^0 and 140^0) where the collimator and couch were set to zero. The dose calculations were computed with AAA algorism. While VMAT plans used to two partial arcs (from 230^0 to 130^0) clockwise (CW) and counterclockwise (CCW) with collimator rotation (15^0 / 345^0) respectively. Firstly, verification plans were created using ArcCHECK phantom in Eclipse v13.7.14 Fig 1. ArcCHECK is a cylindrical phantom with a three-dimensional array of 1386 diode detectors, arranged in a spiral pattern, with 10 mm sensor spacing[12][13]. The measured dose distribution was analyzed by using SNC patient application "ArcCHECK" V6.7.3 (Sun Nuclear Corporation, Melbourne, FL, USA)" and 3DVH software V 3.3.1.

3DVH software evaluated the dose difference with the ArcCHECK planned dose perturbation (ACPDP) calculator (Figure1). The 3DVH software requires reference and comparison data; the patient plan DICOM files RT Plan, RT Dose and RT Structure as a reference and aMapCHECK measurement file with extension ".acml", to compare the dose difference between the ArcCHECK measurement and the TPS calculation. The dose portend by the ArcCHECK-Planned Dose Perturbation (ACPDP) was calculated from the patient plan DICOM files and the ArcCHECK plan DICOM files. These dose distributions could then be compared in terms of the DVH of each structure with the measured dose distribution. Further, the gamma pass rate was used to quantify the agreement between the calculations and measurements Fig 2.TG-218 and many guidelines have investigated the acceptance scales of patient quality assurance, and they have suggested the gamma pass rate should be ≥ 95% with 3% dose difference and 3 mm distance-to-agreement criterion[14]. The percentage dose differences%DDs were calculated for the planning target volume PTV and the organs at risk OAR with 3DVHsoftware.The maximum dose D_{Max}, the mean dose D_{Mean}, in addition to the volume received 95% of the dose V95 and the dose that covers2%, 50%and 98% of the volume D2, D50 and D98were calculated by "Eclipse v13.7.14". Whilst, for OARs, D_{Max}, D_{Mean} and V15, V25, V35, V50 and V70which were predicted by ACPDP–were compared with those of the TPS. The percentage dose difference %DD isdefined as:

$$\%DD = (D_{3DVH}-D_{TPS})/D_{TPS} \times 100$$

D_{3DVH} represents the dose by 3DVH, whereas D_{TPS} represents the dose calculated by Eclipse v13.7.14. The correlations between the gamma pass rate (3%/3mm, 2%/2mm and 1%/1mm criterion) and %DD were examined with MS Office Professional Plus "Excel" 2013.

RapidArc					IMRT				
Structure	Parameter	%DD	r	p-value	Structure	Parameter	%DD	r	p-value
PTV	D_{Mean}	2.019	0.6939	<0.05	PTV	D_{Mean}	0.485	0.6919	0.05
PTV	$D_{98\%}$	2.248	0.6658	<0.05	PTV	$D_{98\%}$	1.183	0.7986	<0.05
Rectum	D_{Mean}	1.900	0.9966	<0.05	Rectum	D_{Mean}	3.211	0.9982	<0.05
Rectum	V_{50Gy}	3.271	0.9982	<0.05	Rectum	V_{50Gy}	3.612	0.9969	<0.05
Bladder	D_{Mean}	0.291	0.9994	<0.05	Bladder	D_{Mean}	0.325	0.9995	0.05
Bladder	V_{50Gy}	1.594	0.9987	<0.05	Bladder	V_{50Gy}	2.23	0.9990	<0.05
Lt.Femur	D_{Mean}	0.970	0.9986	<0.05	Lt.Femur	D_{Mean}	3.081	0.9996	<0.05

Table 2: Percentage dose difference and correlation between %DD and gamma pass rate.

III. Results

Prior 3D dose analyses, we recorded the 2D planar dose that was detected by ArcCHECK phantom V6.7.3 (Sun Nuclear Corporation). 2D gamma analyses showed goodharmony between the measured and calculated doses (gamma passing rate >97.5% for all patients (3%/3 mm, global normalization, threshold 10%)), proving that ordinary 2D patient-specific QA was mostly usefulness.Table 1 shows the mean gamma pass rates and standard deviations.

Resultant dose distributions which obtained from pretreatment verification plans; RT dose, RT plan and RT structure that exported from TPS were imported to the 3DVH software. The dose volume histograms calculated by 3DVH were compared with the DVHs predicted by the TPS using these parameters: D_{Mean}& V50 for Rectum and Bladder, D_{Mean}&D_{Max} for Femoral Heads, and D_{Mean}&D98 for PTV.

Table 2shows the %DDsbetweenArcCHECK measurements and Eclipse V13.7.14 for the PTV and OARs, for both techniques.The %DD was less than 3% for target volume, and 4% for normal organs for VMAT technique. The percentage dose difference was correlated with the gamma pass rate for D_{Mean} and D98 of PTV,

D_{Mean} and V50 of Rectum & Bladder, D_{Mean} and D_{Max} of Femoral heads ($p<0.05$). These results referred to a strong correlation (i.e., $r > 0.7$).

Table 1: Gamma pass rates and standard deviations.

RapidArc

Gamma Pass Rate	3%,3mm	SD	2%,2mm	SD	1%,1mm	SD
ArcCHECK	99.11	0.66	93.55	4.14	67.76	9.90
3DVH	99.24	0.22	97.80	0.54	85.05	3.54

IMRT

Gamma Pass Rate	3%,3mm	SD	2%,2mm	SD	1%,1mm	SD
ArcCHECK	96.79	1.4	85.99	3.57	57.87	6.62
3DVH	98.03	0.99	90.95	2.34	68.59	6.32

On the other hand,the percentage dose differences in case of IMRT technique were smaller than those of VMAT. There was no statistical significance. Figures 3 and 4 show the relation between %DD and the gamma pass rate for each volume of IMRT technique. It can be seen that the percentage dose difference for the mean dose of PTV decreases with the increasing the gamma pass rate for both techniques. However, there was no apparent correlation for other volumes, except Rectum and Rt.Femur in case of IMRT.

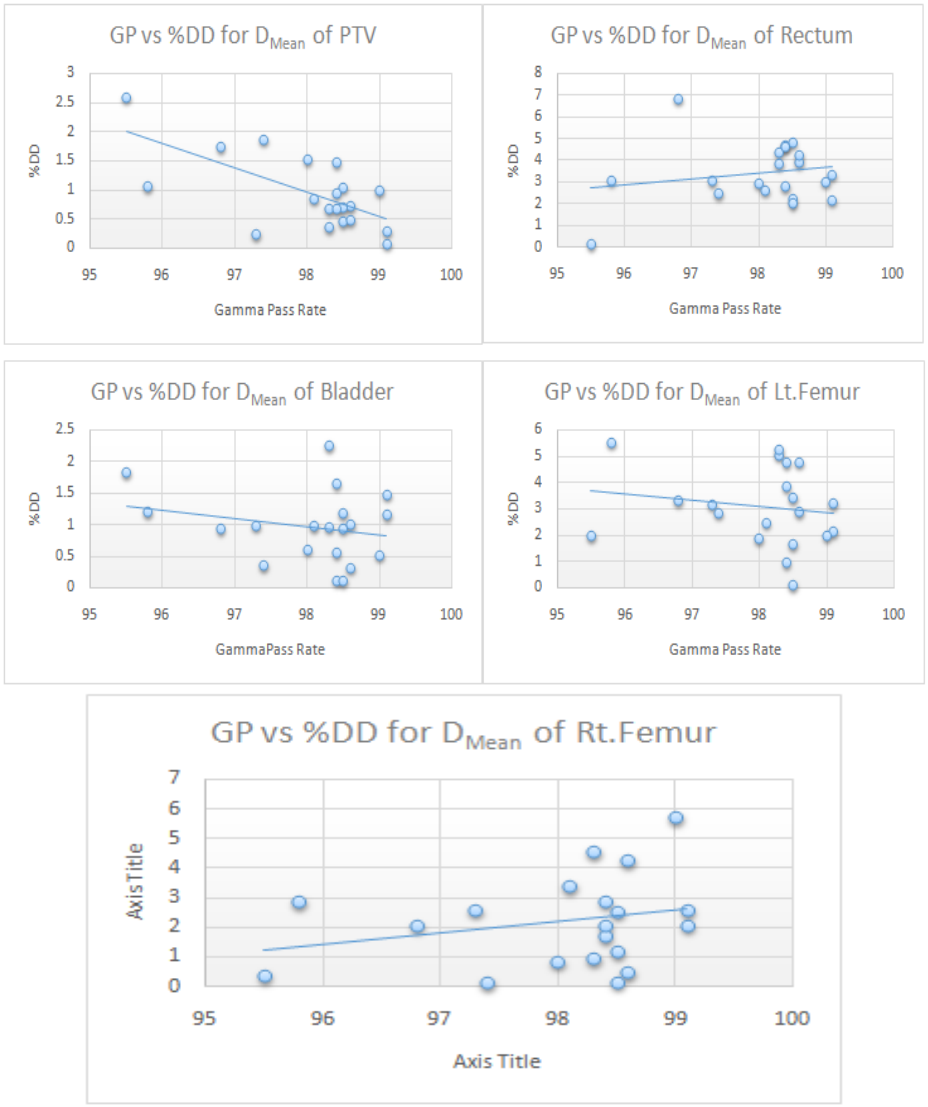

Figure 3: Correlation between percentage dose difference and gamma pass rate for each structure in the cases of IMRT Technique.

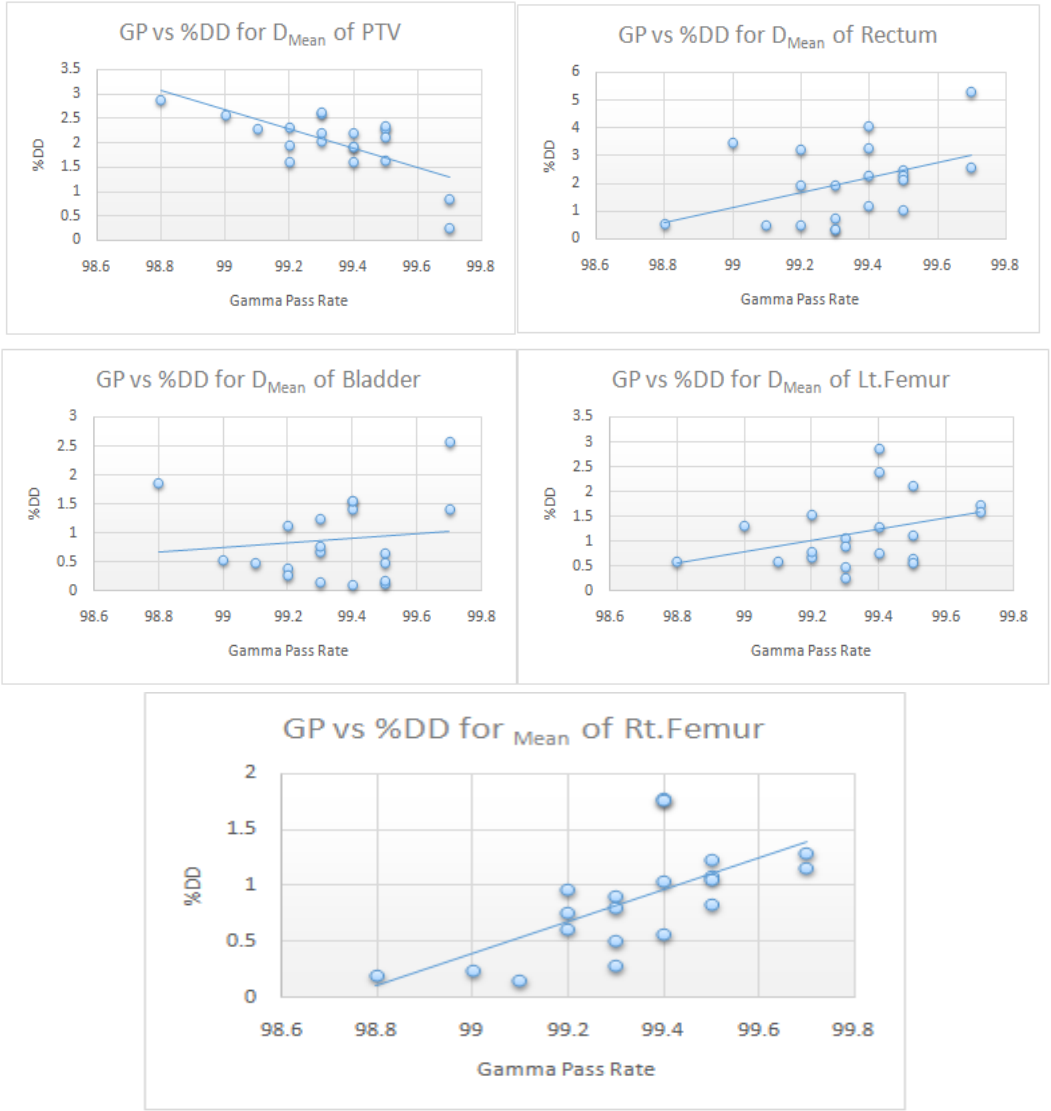

Figure 4: Correlation between percentage dose difference and gamma pass rate for each structure in the cases of VMAT Technique

IV. Discussion

In external beam radiation therapy the precise patient positioning is essential with the usage of complicated treatment plans. Patient-specific pretreatment verification of advanced dosimetric techniques is strongly recommended for all patients in order to detect any potential errors in treatment planning process and machine deliverability, and is thus performed routinely in many clinics.

In this study, patient-specific pretreatment QA was performed with ArcCHECK dosimetric device, and analyzed by 3DVH software. Furthermore, the percentage dose difference and the mean gamma pass rates were evaluated for PTV and OARs. The accuracy of the ArcCHECK-3DVH system has been validated by several authors, such as Infusino et al.[15].Our study is to confirm IMRT and VMAT QA with ArcCHECK detector, and to compare the results with those of the 3DVH software. The gamma pass rate evaluated with this cylindrical phantom and 3DVH software. Although the results for both treatment techniques matched well.

IMRT leads to an increase in monitor units comparable with VMAT and therefore is likely to increase the integral dose[16]. The decrease in MUs required with VMAT reduces exposure to leaked radiation from the gantry head, which is a concern regarding the development of second cancers. However VMAT delivers dose circumferentially around patients, potentially leading to an increase in the volume of tissue exposed to low radiation doses[17]. While we found that the monitor units with VMAT was significantly lower than for IMRT, as both the delivered dose distribution and leakage radiation play a role in depositing dose outside the treatment volume.

V. Conclusion

In our study, we evaluated two dosimetric techniques using ArcCHECK and 3DVH software. The dosimetry systems yielded similar results for the gamma pass rate using the 3%/3 mm criterion. Using 3DVH software, we were able to estimate the accuracy of dose distribution through the DVH for target and normal organ volumes. The mean gamma pass rates exceeded 97.5% for the 3%/3 mm criterion. In the cases of IMRT, the mean gamma pass rates of ArcCHECK and 3DVH were estimated to be higher than those of VMAT. The %DD was less than 3% for target volume, and 4% for normal organs, and the percentage dose difference was correlated with the gamma pass rate for PTV and D_{Mean} ($p < 0.05$).

Reduced MUs does have many advantages in the running of radiotherapy departments including extended linear accelerator lifespan, reduced shielding requirements as well as the likely economic benefit of faster treatment and throughput. The reduction in treatment times with use of VMAT are particularly useful for prostate cancer treatment.

Furthermore in addition, there was no statistical significance found. From our results, we recommend using VMAT for prostate cancer patients.

References

[1]. S. Webb, Intensity-modulated radiation therapy. 2015.
[2]. R. Asur, K. T. Butterworth, J. A. Penagaricano, K. M. Prise, and R. J. Griffin, "High dose bystander effects in spatially fractionated radiation therapy.," Cancer Lett., 2015.
[3]. D. Craft, D. Mcquaid, J. Wala, W. Chen, E. Salari, and T. Bortfeld, "Multicriteria VMAT optimization Multicriteria VMAT optimization," vol. 686, no. 2012, pp. 1–19, 2014.
[4]. M. Oliver, W. Ansbacher, and W. A. Beckham, "Comparing planning time, delivery time and plan quality for IMRT, RapidArc and tomotherapy," J. Appl. Clin. Med. Phys., vol. 10, no. 4, pp. 117–131, 2009.
[5]. J. H. Park, T. G. Kim, S. K. Min, and B. Do Park, "Comparison of 3DVH Software with Two-dimensional Array Systems on Pretreatment Verification for Volumetric-modulated Arc Therapy," J. Nucl. Med. Radiat. Ther., vol. 07, no. 02, 2016.
[6]. V. Chaswal, M. Weldon, N. Gupta, A. Chakravarti, and Y. Rong, "Commissioning and comprehensive evaluation of the ArcCHECK cylindrical diode array for VMAT pretreatment delivery QA," J. Appl. Clin. Med. Phys., vol. 15, no. 4, pp. 212–225, 2014.
[7]. P. Fenoglietto, B. Laliberté, N. Aillères, O. Riou, J. B. Dubois, and D. Azria, "Eight years of IMRT quality assurance with ionization chambers and film dosimetry: Experience of the montpellier comprehensive cancer center," Radiat. Oncol., 2011.
[8]. D. Ĺtourneau, J. Publicover, J. Kozelka, D. J. Moseley, and D. A. Jaffray, "Novel dosimetric phantom for quality assurance of volumetric modulated arc therapy," Med. Phys., 2009.
[9]. S. Bresciani et al., "Tomotherapy treatment plan quality assurance: The impact of applied criteria on passing rate in gamma index method," Med. Phys., 2013.
[10]. E. Infusino et al., "Medical Dosimetry Initial experience of ArcCHECK and 3DVH software for RapidArc treatment plan veri fi cation," Med. Dosim., vol. 39, no. 3, pp. 276–281, 2017.
[11]. A. J. Olch, "Evaluation of the accuracy of 3DVH software estimates of dose to virtual ion chamber and film in composite IMRT QA," Med. Phys., 2012.
[12]. Sun Nuclear Corporation, "ArcCHECK^{TM} User ' s Guide. The Ultimate 4D QA Solution," 2009.
[13]. D. Tools, "3DVH Reference Guide Complete 3D Patient Dose Analysis."
[14]. D. A. Low, W. B. Harms, S. Mutic, and J. A. Purdy, "A technique for the quantitative evaluation of dose distributions," no. June 1997, pp. 656–661, 1998.
[15]. M. Saito et al., "Comparison of DVH-based plan veri fi cation methods for VMAT : ArcCHECK-3DVH system and dynalog-based dose reconstruction," no. November 2016, pp. 206–214, 2017.
[16]. F. Foroudi et al., "A dosimetric comparison of 3D conformal vs intensity modulated vs volumetric arc radiation therapy for muscle invasive bladder cancer," pp. 1–10, 2012.
[17]. P. I. Emea, "IMRT and VMAT Delivery MLC Design and Dosimetric Parameters."

Ibrahim El Hamamsi,et.al. "Comprehensive Study between calculated and Measured DVHs for Prostate Cancer Patients Using IMRT/RapidArc Dosimetric Techniques" *IOSR Journal of Applied Physics (IOSR-JAP)*, 12(1), 2020, pp. 41-46.