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Evaluation of Eclipse 3D plans using an independent treatment planning system

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Original Article

Abstract

Purpose: The goal of the current investigation was to compare complex 3D conformal plans generated on Eclipse™ treatment planning system (TPS) with independent dose calculations from radiation oncology planning system (ROPS™) TPS used as a secondary quality assurance check. **Methods:** Fifteen cancer patients that were treated with complex conformal treatment plans with cobalt and linac beams, using Eclipse TPS, were selected for this study. The structure sets, treatment beam data and prescription information were exported from the Eclipse TPS using DICOM-RT export. Using custom software, these data were imported into ROPS TPS. Independent dose calculation on the ROPS planning system using Clarkson summation algorithm was done. The dose volume histograms (DVH) from both planning systems were extracted and analyzed using custom software. Dose assessment was accomplished by defining criteria based on gross tumor volume (GTV) dose coverage, dose homogeneity and mean dose. For organs at risk (OAR) other than GTV, the main dose parameters were, mean dose and percentage of volume receiving 95% of prescription dose. **Results:** For the GTV, all 15 cases met the criteria set for the mean dose and dose homogeneity index. However, breast cases were found to have deviation in the percentage volume receiving the 95% of prescription dose. **Conclusion:** Using the criteria set for plan acceptance, all the 15 clinical cases were evaluated. Except for breast tangent plans, all plans passed all the criteria set. The large deviation for breast tangent plans was attributed to differences in dose calculation algorithms.

Keywords: Quality Assurance, 3D Treatment Planning, DVH analysis, Eclipse TPS, ROPS TPS

1. Introduction

Modern 3D planning is more complex than in the past. The complexity arises due to the fact, the use of MLC with fine leaves allows the exploitation of irregular shaped beams, wedged beams with physical as well as enhanced dynamic wedges, including field-in-field beam configurations. Sometimes non-coplanar arrangement with table and collimator angles is used. Once, the 3D plan is generated, unlike IMRT, there are no specific regulations for the verification of these plans before the patient is treated. Independent dose calculations using hand calculations[1] has many limitations due to the complexity of these fields. Even experimental measurements using hybrid plan and planar dose distribution measurements verify the phantom dose only and do not directly related to actual dose received by the patient. Under these circumstances, it is highly desirable to verify the entire plan in another independent planning system. Dose-volume histograms provide key information to radiation oncologists when they assess the adequacy of a patient treatment plan in radiation therapy.

The use of dose volume histograms alone has its pitfalls especially they lack the positional information. This has been described by Kessler *et al.*[2] In addition, dose volume histograms do carry errors propagated through several parameters, such as dose grid and these have been examined by Panitsa *et al.*[3] While the DVH data

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suffers from loss of position detail, it has its merits in allowing various biological models based on tumor control probability (TCP) and normal tissue complication probability (NTCP) concepts described by several investigators.[4, 5, 6, 7] In order to use the DVH data in a concise manner several dose indices were defined. Feuvret *et al.*[8] defined conformity index. Leung *et al.*[9] defined conformation number (CN) and conformal index (COIN). The radiation conformity index was defined by Knoos *et al.*[10] Pyakuryal *et al.*[11] developed HART tool for DVH analysis. Weinberg *et al.*[12] investigated the source of differences in DVH generation in planning systems. The uncertainties in DVH were also investigated by Henriquez *et al.*[13] There are not many investigations that reported the DVH comparison of different treatment planning systems for the same patient data including same beam plan configuration. Nelms *et al.*[14] reported comparison of DVH between Pinnacle and PlanIQ using very similar geometrical targets. Ayyangar *et al.*[15] reported DVH comparison of the same patients in two different planning systems viz. Pinnacle and Corvus. They reported deviations as much as 15% for organs at risk other than CTV/GTV.

Comparing the DVHs of GTV as well as all other structures independently is a much better approach than point dose calculation or hybrid plan evaluation. Nelson *et al.*[16] have described an independent TPS verification system based on DICOM-RT transfer and convolution algorithm. The system generates independent DVH for comparison with Eclipse system. Many Commercial systems, MOBIUS™ (Mobius Medical Systems, Houston, TX), COMPASS™ (IBA, Inc) 3DVH (Sun Nuclear Corporation), RayStation (RaySearch Laboratories, Stockholm, Sweden) RadCalc(®) (LifeLine Software Inc., Austin, USA) currently have similar software that use patient data transfer from the TPS. Unfortunately there are not many publications that compared DVH analysis of several patients inter-comparing these systems.

In a recent paper by Anil Kumar *et al.*[17], a quality assurance method for treatment plan verification was described. This method exported structure sets and plan data from Eclipse planning system into the ROPS planning system. On the ROPS system, the dose was re-calculated and the DVH were generated. The DVHs from both planning systems were compared using Excel spreadsheet. Since it was comparison of two independent planning systems, the monitor units were not identical. In this current paper more detailed evaluation of this method was attempted using 10 clinical cases that used linac machine and 5 clinical cases that used cobalt-60 machine. Since the method in the quoted paper was for doing quality assurance, in the current paper, all DVHs were computed on the ROPS TPS using the same monitor units as with the Eclipse plans..

2. Methods and Materials

In the current investigation, all the Eclipse plans used version 8.8 using AAA algorithm, except for four plans that used the new version 13.6. All plans used tissue heterogeneity correction. For each patient plan, the CT scans were directly imported into ROPS from the Eclipse system using the scan export. Next, for each patient, the structure sets and plan information from the Eclipse system were exported using DICOM-RT as ASCII files. Using custom software written for the ROPS planning system, these data were re-formatted so it can be read by the ROPS planning system.

2.1. ROPS

ROPS TPS is based on CENTOS 6.4 Linux operating system and was commissioned using BJR25 depth dose for Cobalt-60 machine. The dose rate, output factors, wedge factors etc. were specific to the actual treatment machine that was used. For LINAC, data from a specific Varian DHX (Dual Head X-Ray) machine was used for commissioning[18] the TPS. Comprehensive treatment planning tests were performed using TG-53 report. For dose calculations, ROPS uses Clarkson scatter integration method. ROPS corrects for tissue heterogeneity by using ray traced equivalent depth. The details of ROPS specifications can be found from the website at https://sites.google.com/site/tjcsrops. The use of ROPS for conformal treatments has been recently reported.[19]

The DICOM-RT regions of interest file consisted of all regions contoured as well as body contours. The dose file consisted of dose volume histograms and the dose to matrix matching each CT image. The plan file consisted of beam parameters such as field sizes, beam angles, wedges, MLC positions, beam weights, dose prescription, number of fractions and monitor units and isocenter position. Using all this information, the ROPS system calculated the dose to the matrix and the dose volume histograms. After the DVH calculations, the analysis consisted of calculating some important dosimetric parameters. This analysis was performed using the data from both planning systems, but outside the planning systems using Excel spread sheets and custom software.

The following describes the parameters and the criteria defined for the comparison of the DVHs. The V95 is the percent volume receiving 95% prescription dose. If the difference between the two systems is less than 5, the target dose coverage was considered in agreement.

The dose homogeneity index HI in the target volume was calculated using
(D5 - D95)/Dp *100 where D5 and D95 represent the dose at 5% and 95% target volume respectively and Dp is the prescription dose. Similar definition was used by Yoon *et al.*[20] and Kataria *et al.*[21] If the difference in HI between the planning systems is less than 5%, the target dose distribution uniformity was considered in agreement. In addition, the mean dose to the target was

also compared. If the ratio between the mean doses of the two systems is between 0.95 and 1.05, the target dose was considered in agreement.

For each structure other than the target volume, the maximum dose, the minimum dose, the volume averaged mean dose and V95 were computed. If the difference in V95 between the two systems is less than 5, the structure dose coverage was considered in agreement. The difference between the mean doses between the two planning systems was computed and was considered in agreement if it is less than 5 Gy.

3. Results

Table 1 shows the results of the DVH analysis for the target volume for all the 15 clinical cases. The regions specified in column 4 already contained adequate margins and are to be considered as equivalent to PTV for all practical purposes. The doses are displayed in units of Gy. The differences in V95 are red color coded if the difference is 5 or more indicating there is 5% or greater difference in the target coverage between both the planning systems. Similarly, HI and mean dose were red color coded, if the criteria were not met. The average and standard deviation of the comparison between the two planning systems is also listed in Table 1. In addition, the p - value from two tailed paired t - test was also computed between the Eclipse and ROPS indices. As can be seen from the Table (column 7), as well as from Figure 1, the dose homogeneity index is within the set criteria.

The difference in V95 between the planning systems from Table 1 column 6 is plotted in Figure 2. We find that only one case out 15 cases did not meet the criteria. This case involves breast plan where the GTV is not covered fully at the 90-95% dose level. This is because of the sloping contour in both medial-lateral as well as craniocaudal direction. The use of traditional wedges does not bring dose uniformity. Figure 3 shows the DVH comparison for this case of breast treatment. It can be seen that the GTV is covered by the prescription dose only at 60-70% level instead of expected 95% isodose line. ROPS calculation shows an increase in dose of 3 Gy at the 40% volume. It is interesting even though the difference in V95 is excessive, the homogeneity index and mean dose are within limits between the two planning systems.

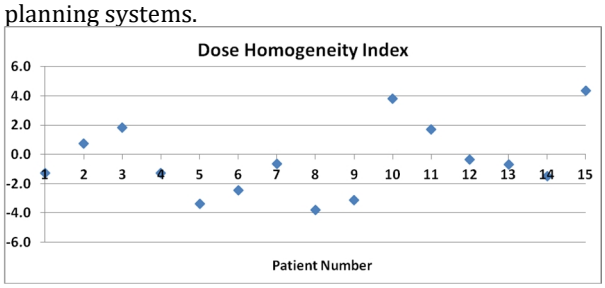

Figure 1: The difference between Eclipse and ROPS in dose uniformity index for the GTV

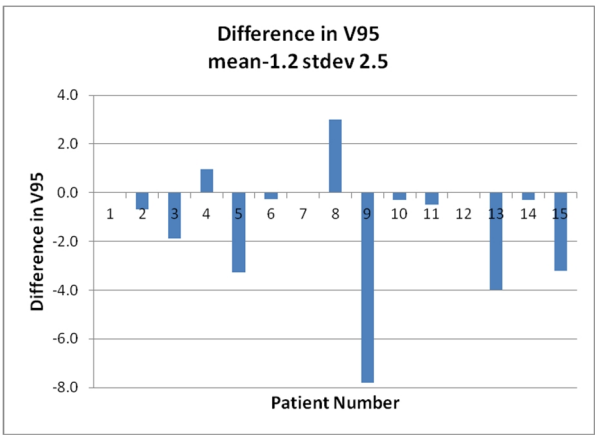

Figure 2: Difference between Eclipse and ROPS in V95 (percent volume receiving 95% dose)

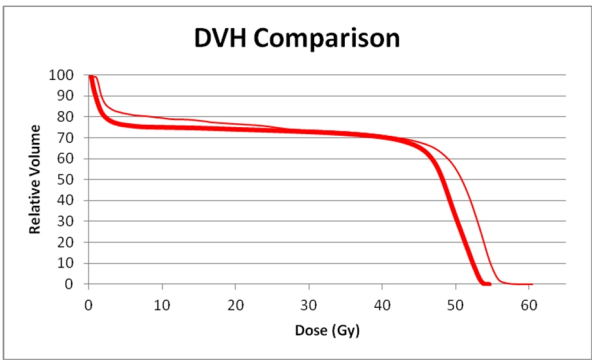

Figure 3: DVH comparison of breast GTV for case#9. Eclipse thick line and ROPS in thin line.

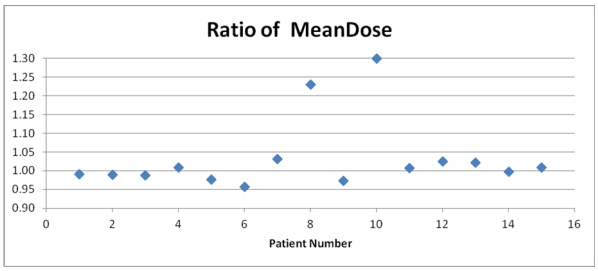

Figure 4: Mean dose ratio between Eclipse and ROPS for the GTV of the clinical plans.

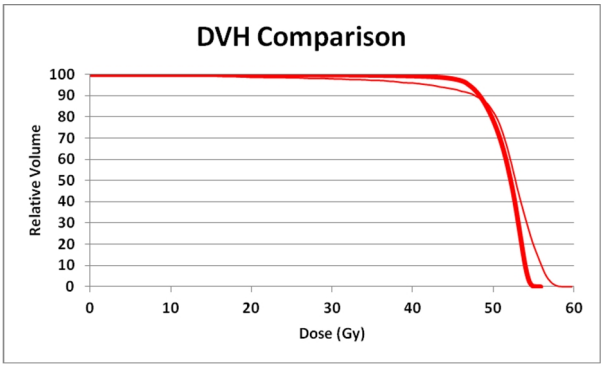

Figure 5: DVH comparison of breast GTV for case#10. Eclipse thick line and ROPS in thin line.

Table 1: DVH parameter analysis for GTV. Parameter values that did not meet the set criteria were marked in red color.

Patient Number	Energy	Treatment Site	Region of Interest	TPS	V95 (%)	HI	Mean Dose (Gy)	D5 (Gy)	D95 (Gy)	Prescription Dose (Gy)
1	6MV 16MV	Ca bladder	CTV	Eclipse	100.0	3.1	50.5	51.8	50.2	50
			CTV	ROPS	100.0	4.4	50.9	53.0	50.8	50
				diff/ratio	0.0	-1.3	1.0			
2	6MV	Ca bladder	Bladder 1.5margin	Eclipse	98.3	5.3	43.5	51.1	48.5	50
			Bladder 1.5margin	ROPS	99.0	4.5	44.0	53.1	50.8	50
				diff/ratio	-0.7	0.7	1.0			
3	16MV	Ca lung	GTV	Eclipse	98.1	7.7	40.5	46.3	42.9	44
			GTV	ROPS	100.0	5.9	41.0	45.5	43.0	44
				diff/ratio	-1.9	1.8	1.0			
4	6MV	Lung	LUNG & METS	Eclipse	100.0	7.0	47.2	52.3	48.8	50
				ROPS	99.0	8.3	46.8	52.6	48.5	50
				diff/ratio	1.0	-1.3	1.0			
5	6MV	Lung	LT LUNG	Eclipse	95.7	9.9	47.6	52.6	47.7	50
				ROPS	99.0	13.3	48.8	56.0	49.3	50
				diff/ratio	-3.3	-3.4	1.0			
6	6MV	Lung	RT LUNG	Eclipse	99.7	8.1	61.6	68.3	64.3	50
				ROPS	100.0	10.5	64.3	69.1	63.8	50
				diff/ratio	-0.3	-2.5	1.0			
7	16MV	Ca esophagus	GTV	Eclipse	100.0	4.4	39.9	41.3	39.5	40
			GTV	ROPS	100.0	5.0	38.7	40.5	38.5	40
				diff/ratio	0.0	-0.6	1.0			
8	6MV 16MV	Ca esophagus	GTV	Eclipse	100.0	5.5	38.8	40.6	38.4	40
			GTV	ROPS	97.0	9.3	31.6	44.7	41.0	40
				diff/ratio	3.0	-3.8	1.2			
9	6MV	Ca lt. breast	GTV	Eclipse	56.2	104.9	24.3	53.0	0.5	50
			GTV	ROPS	64.0	108.0	25.0	55.4	1.3	50
				diff/ratio	-7.8	-3.1	1.0			
10	6MV	Breast	LT BREAST	Eclipse	93.5	14.4	34.0	54.2	47.0	50
				ROPS	91.0	10.6	26.1	47.8	42.4	50
				diff/ratio	-0.3	3.8	1.3			
11	Cobalt-60	Cervical spine	GTV	Eclipse	97.5	11.0	58.3	63.2	56.7	59.4
				ROPS	98.0	9.3	57.8	62.6	57.1	59.4
				diff/ratio	-0.5	1.7	1.0			
12	Cobalt-60	Abdomen	GTV	Eclipse	100.0	5.1	48.1	52.2	49.7	50
			GTV	ROPS	100.0	5.4	46.9	52.0	49.3	50
				diff/ratio	0.0	-0.3	1.0			
13	Cobalt-60	Abdomen	GTV	Eclipse	38.0	98.8	18.8	40.0	0.5	40
			GTV	ROPS	42.0	99.5	18.4	40.4	0.6	40
				diff/ratio	-4.0	-0.7	1.0			
14	Cobalt-60	Rt post. brain	GTV2	Eclipse	99.8	4.3	29.2	30.6	29.3	30
				ROPS	100.0	5.8	29.3	31.1	29.4	30
				diff/ratio	-0.3	-1.5	1.0			
15	Cobalt-60	Cervical spine	GTV	Eclipse	95.8	13.5	10.2	21.7	19.1	19.8
			GTV	ROPS	99.0	9.2	10.1	21.5	19.6	19.8
				diff/ratio	-3.2	4.3	1.0			
			Average		-1.2	-0.4	1.0			
			Std. dev		2.5	2.5	0.1			
			p-value		0.164	0.536	0.281			

Table 2: DVH parameter analysis for critical structures. Parameter values that did not meet the set criteria were marked in red color.

Patient Number	Structure	TPS	V95 (%)	Maximum Dose(Gy)	Minimum Dose(Gy)	Mean Dose (Gy)
1	Rectum	Eclipse	75.0	52.42	34.05	42.07
	Rectum	ROPS	71.0	54.14	32.18	41.28
		diff	4.0	-1.72	1.87	0.79
2	Bladder	Eclipse	100.0	51.24	48.27	49.22
	Bladder	ROPS	100.0	52.91	50.24	50.98
		diff	0.0	-1.67	-1.97	-1.76
3	Spinal Cord	Eclipse	45.8	45.59	0.54	21.01
	Spinal Cord	ROPS	47.0	45.09	0.45	20.73
		diff	-1.2	0.50	0.09	0.28
4	Heart	Eclipse	0	3.3	0.21	0.65
	Heart	ROPS	0	3.5	0.5	0.95
		diff	0.0	-0.20	-0.29	-0.30
	Lt. lung	Eclipse	9.62	52.81	0.22	18.77
	Lt. lung	ROPS	11	53.5	0	17.62
		diff	-1.4	-0.69	0.22	1.15
	PTV	Eclipse	99.46	53.37	42	46.18
	PTV	ROPS	100	53.5	32.5	41.39
		diff	-0.5	-0.13	9.50	4.79
	Rt. lung	Eclipse	0	23.29	0.14	3.23
	Rt. lung	ROPS	0	23	0	2.51
		diff	0.0	0.29	0.14	0.72
	Spinal cord	Eclipse	-0.02	31.34	0	8.54
	Spinal cord	ROPS	0	27.5	0	7.77
		diff	0.0	3.84	0.00	0.77
	Lung-GTV	Eclipse	8.89	52.7	0.22	18.57
	Lung-GTV	ROPS	11	53.5	0	17.48
		diff	-2.1	-0.80	0.22	1.09
	Shell	Eclipse	0.46	50.34	1.51	15.03
	Shell	ROPS	22	53.5	1	18.89
		diff	-21.5	-3.16	0.51	-3.86
	4mm	Eclipse	90.08	53.38	31.15	40.42
	4mm	ROPS	92	53.5	25	37.17
		diff	-1.9	-0.12	6.15	3.25
	2mm	Eclipse	96.53	53.37	34.94	42.5
	2mm	ROPS	98	53.5	28	38.95
		diff	-1.5	-0.13	6.94	3.55
	PTV50Gy	Eclipse	99.46	53.38	42.01	46.18
	PTV50Gy	ROPS	100	53.5	32.5	41.39
		diff	-0.5	-0.12	9.51	4.79
	6mm	Eclipse	80.91	53.37	23.9	36.5
	6mm	ROPS	84	53.5	16.5	32.5
		diff	-3.1	-0.13	7.40	4.00
5	Spinal cord	Eclipse	-0.11	26.06	0	9.58
	Spinal cord	ROPS	0	25	0	8.14
		diff	-0.1	1.06	0.00	1.44
	Rt. lung	Eclipse	0	20.65	0	3.5
	Rt. lung	ROPS	0	20	0	3.33
		diff	0.0	0.65	0.00	0.17
	Lt. lung	Eclipse	4.49	52.72	0.61	15.28
	Lt. lung	ROPS	9	57.5	0.5	16.23
		diff	-4.5	-4.78	0.11	-0.95
	Heart	Eclipse	1.25	51.76	1.56	11.71
	Heart	ROPS	1	52.5	1	10.91
		diff	0.3	-0.74	0.56	0.80
	Esophagus	Eclipse	-0.45	32.62	0.39	10.65

	Esophagus	ROPS	0	32.5	0.5	9.73
		diff	-0.5	0.12	-0.11	0.92
	PTV50Gy	Eclipse	95.73	53.25	44.4	47.58
	PTV50Gy	ROPS	99	57.5	44.5	48.76
		diff	-3.3	-4.25	-0.10	-1.18
	Lung-GTV	Eclipse	4.25	52.56	0.61	15.2
	Lung-GTV	ROPS	9	57.5	0.5	16.61
		diff	-4.8	-4.94	0.11	-1.41
6	Esophagus	Eclipse	-0.15	30.85	0.41	8.1
	Esophagus	ROPS	0	29.04	0	6.63
		diff	-0.2	1.81	0.41	1.47
	GTV	Eclipse	100	69.21	64	65.57
	GTV	ROPS	100	72.6	62.04	64.33
		diff	0.0	-3.39	1.96	1.24
	Heart	Eclipse	-0.01	37.79	0.11	8.41
	Heart	ROPS	0	35.64	0	6.72
		diff	0.0	2.15	0.11	1.69
	Lung Rt-GTV	Eclipse	13.91	69.33	0.51	24.78
	Lung-Rt-GTV	ROPS	20	73.26	0	24.65
		diff	-6.1	-3.93	0.51	0.13
	Lung_Lt.	Eclipse	-0.02	24.83	0.24	4.05
	Lung_Lt.	ROPS	0	31.68	0	3.22
		diff	0.0	-6.85	0.24	0.83
	Lung_Rt.	Eclipse	15.63	69.34	0.51	25.22
	Lung_Rt.	ROPS	20	73.26	0	24.68
		diff	-4.4	-3.92	0.51	0.54
	PTV 66PHY	Eclipse	96.08	70.52	57.84	62.05
	PTV-66	ROPS	99	73.26	50.82	58.58
		diff	-2.9	-2.74	7.02	3.47
	Spinal Canal	Eclipse	-0.1	43.71	0.13	17.66
	Spinal Canal	ROPS	0	42.24	0	14.91
		diff	-0.1	1.47	0.13	2.75
7	Spinal cord	Eclipse	0.0	33.82	0.00	11.45
	Spinal cord	ROPS	0.0	34.82	0.39	11.63
		diff	0.0	-1.00	-0.39	-0.18
	Heart	Eclipse	71.6	42.54	21.37	30.62
	Heart	ROPS	70.0	41.79	17.41	27.62
		diff	1.6	0.75	3.96	3.00
	Liver	Eclipse	27.0	42.67	0.66	15.45
	Liver	ROPS	35.0	42.56	0.39	16.02
		diff	-8.0	0.11	0.27	-0.57
	Lt. Kidney	Eclipse	0.0	37.39	1.34	12.24
	Lt. Kidney	ROPS	0.0	38.69	0.77	12.00
		diff	0.0	-1.30	0.57	0.24
	Rt. Kidney	Eclipse	0.0	19.42	0.60	3.19
	Rt. Kidney	ROPS	0.0	23.60	0.39	2.86
		diff	0.0	-4.18	0.21	0.33
8	Cord	Eclipse	50.97	42.14	0.07	19.28
	Cord	ROPS	40	44.1	0	18.61
		diff	11.0	-1.96	0.07	0.67
9	Lt. lung	Eclipse	0	47.8	0.48	17.33
	Lt. lung	ROPS	4	51.5	0.76	18.23
		diff	-4.0	-3.70	-0.28	-0.90
	Rt. lung	Eclipse	-0.01	4.57	0	0.32
	Rt. lung	ROPS	0	11.44	0.38	1
		diff	0.0	-6.87	-0.38	-0.68
	Heart	Eclipse	0.01	47.6	0.48	17.53
	Heart	ROPS	4	51.5	1.14	17.59
		diff	-4.0	-3.90	-0.66	-0.06
	Spinal cord	Eclipse	-1.85	0.42	0.02	0.14
	Spinal cord	ROPS	0	4.96	0.57	0.87
		diff	-1.9	-4.54	-0.55	-0.73
10	Lung_Lt.	Eclipse	10.72	52.84	1.48	20.33
	Lung_Lt.	ROPS	14	55.67	0.85	20.82
		diff	-3.3	-2.83	0.63	-0.49
	Heart	Eclipse	5.1	53.41	1.81	17.8
	Heart	ROPS	5	55.89	1.06	16.19
		diff	0.1	-2.48	0.75	1.61
	Spinal Cord	Eclipse	-0.03	1.71	0.62	0.94

	Spinal Cord	ROPS	0	1.49	0.64	0.9
		diff	0.0	0.22	-0.02	0.04
	Lung_Rt.	Eclipse	0	24.07	0	0.96
	Lung_Rt.	ROPS	0	41.65	0.64	1.3
		diff	0.0	-17.58	-0.64	-0.34
11	Spinal cord	Eclipse	0.0	12.92	0.00	2.47
	Spinal cord	ROPS	0.0	1.80	0.00	0.38
		diff	0.0	11.12	0.00	2.09
12	Rectum	Eclipse	71.3	50.42	8.04	27.80
	Rectum	ROPS	79.0	50.50	6.50	27.02
		diff	-7.7	-0.08	1.54	0.78
	Bladder	Eclipse	100.0	55.29	49.81	51.41
	Bladder	ROPS	100.0	55.50	47.50	49.79
		diff	0.0	-0.21	2.31	1.62
13	Rt. kidney	Eclipse	-2.1	1.10	0.24	0.44
	Rt. kidney	ROPS	0.0	1.60	0.00	0.41
		diff	-2.1	-0.50	0.24	0.03
	Bladder	Eclipse	0.0	7.61	0.90	1.92
	Bladder	ROPS	0.0	5.20	0.80	1.70
		diff	0.0	2.41	0.10	0.22
	Lt. kidney	Eclipse	-1.3	1.36	0.23	0.46
	Lt. kidney	ROPS	0.0	2.00	0.00	0.43
		diff	-1.3	-0.64	0.23	0.03
14	Left eye	Eclipse	0.0	0.18	0.10	0.12
	Left eye	ROPS	0.0	0.67	0.00	0.09
		diff	0.0	-0.49	0.10	0.03
	Right eye	Eclipse	0.0	0.35	0.19	0.23
	Right eye	ROPS	0.0	0.67	0.00	0.22
		diff	0.0	-0.32	0.19	0.01
15	Spine	Eclipse	0.0	11.64	0.27	4.33
	Spine	ROPS	0.0	10.49	0.00	3.85
		diff	0.0	1.15	0.27	0.48
	Average		-1.5			0.7
	Std.Dev.		4.0			1.6
	p-value		0.01			0.002

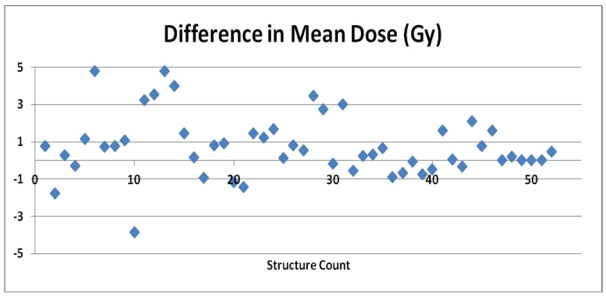

Figure 6: Difference in mean dose between Eclipse and ROPS for all the structures other than the prescription GTV.

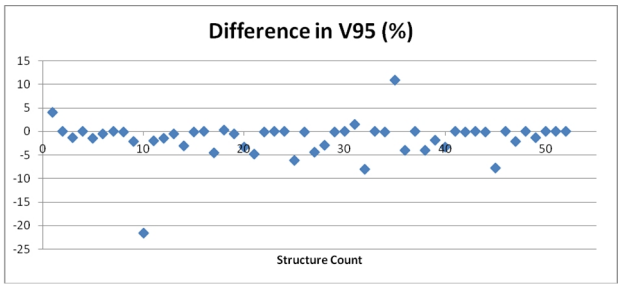

Figure 7: Difference between Eclipse and ROPS in V95 (percent volume receiving 95% of prescription dose) for all the structures other than prescription GTV.

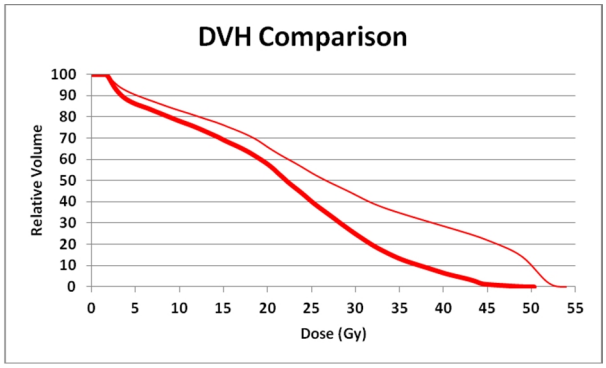

Figure 8: DVH comparison of SHELL structure for patient #4. Eclipse thick line and ROPS in thin line.

Figure 4 shows the ratio of mean dose (from column 8 of Table 1) between Eclipse and ROPS for the GTV. It can be seen except for cases #8 and #10, all the ratios indicate agreement within 5%. It appears that we see more disagreement for the cases of breast and esophagus. The DVH comparison for case #10 is shown in Figure 5. The disagreement in mean dose ratio is caused by lower dose coverage in ROPS between 90-100% volumes.

Table 2 shows comparison data for structures other than GTV or CTV. The structure, BODY that represents the skin on each CT slice has been omitted. Once again, red colored data indicates differences between Eclipse and ROPS using the above specified criteria. The average, standard deviation and p - values of the comparison between the two planning systems are also listed in Table 2.

Figure 6 shows the difference in mean dose (from column 7 of Table 2) in Gy for all the 52 structures from the 15 clinical cases. It can be seen that the variation is within 5 Gy. This should be acceptable for these structures which are shielded from the GTV. Figure 7 shows the difference in V95. It can be seen that 5 out of 52 structures are off by more than 5%. The DVH plot for the structure that is off by 21.6 % is shown in Figure 8. It can been that even though the mean dose for this structure is within limits, ROPS is indicating higher dose although to a smaller volume.

4. Discussion

From the statistical analysis shown in Table-1, it is clear that the p-value is greater than 0.05 indicates that there is no significant difference in the distributions of mean dose values between ROPS and Eclipse planning systems for the target structures. However, the p-values in Table -2 clearly show $p < 0.05$ which indicates, there is significant deviation in the dose calculated for organs outside the target volume. This could mean that the dose in penumbra region could be causing this difference.

There are many reasons why discrepancies can occur between the two planning systems. These are listed below.

It has been well demonstrated in literature that planning systems do not calculate the DVH accurately. Several articles in the literature[22, 23, 24] demonstrated this by using finer grid calculation. Variations in tumor volume delineation and volume calculations cause discrepancies in planning systems.[25] While Eclipse uses 512 × 512 CT matrix, ROPS scales them down to 256 × 256 matrix. This causes error in region boundaries and volume calculations. In general ROPS volumes are 15% larger than Eclipse. Differences in the tissue heterogeneity correction methods can account for large variations between planning systems.

Differences in dose calculation algorithms: While Eclipse used AAA algorithm in the current investigation, ROPS used Clarkson based algorithm for dose calculations. This accounts for the major differences we have seen in the case of breast and esophagus. The Clarkson dose calculation method used by ROPS assumes full scatter conditions. However, for breast treatments there is considerable amount of missing tissue not only in transverse images but also in craniocaudal direction. Although ROPS accounts for equivalent tissue depth, lateral scatter was not corrected for tissue heterogeneity. The convolution algorithm used by Eclipse is relatively more accurate in these cases.

While it is desirable to make this comparison with a TPS with more robust dose calculation model, the main reason to take up this project was the fact that ROPS was described[17] as a low-cost solution. While improving the

dose calculation grid makes minor improvements, accurate dose calculation model makes the bulk of the difference. It is highly desirable that in future the dose calculation model in ROPS be improved, to make this more acceptable.

5. Conclusion

This work demonstrates the use of ROPS as a QA verification tool for Eclipse plans. Although the agreement in most cases is quite acceptable, in some cases it is unacceptable due to dose calculation algorithm differences. While it is desirable to use a better dose calculation model, in the meanwhile, the ROPS system can be used as a verification tool, with this knowledge.

Conflict of Interest

The authors declare that they have no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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