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Original Article

Accuracy Verification of the Plan Evaluation Tools on Eclipse Treatment Planning System Version 8.1

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Abstract

Objectives: Performance of the dose display and cumulative dose volume histogram(DVH) tools on Eclipse version 8.1 treatment planning system (TPS), was investigated using IAEA TRS-430 test protocol.

Materials & Methods: All tests were carried out by using a simple plan on a water-like test phantom. The agreement of isodose lines with color wash and point doses, reports of the hot spot and cold spot dose, correct representation of relative and absolute dose on plan normalization and consistency of dose display with varied total dose were evaluated. For cumulative DVH, some basic parameters for DVH calculations such as volume of structure, dimension of histogram dose bin and calculation grid were investigated. Relative or absolute mode DVH, DVH dose statistics and DVH statistical reports were all the subjects of interest for assessment the cumulative DVH characteristics.

Results: Consistency of the dose display tool was well maintained, since most of the deviations on all tests were found to be within ± 2 mm. For cumulative DVH, discrepancies of the calculated volumes, ranging in size from < 1 cc (optic chiasm) to > 10,000 cc (body) were shown to be within ± 2 % of the known volumes. The reported doses and volumes on DVH statistical reports and graphs were exhibited accurately. Dose statistics were correctly presented. Varying histogram dose bin from 1 cGy to 5 and 10 cGy, showed the variations in DVH calculations about 2% and 5%, respectively. In the present work, size of the calculation grid showed no effect on DVH calculations. Relative or absolute mode DVH were also found to effectively perform.

Discussion & Conclusion: General performance of the Eclipse 8.1 plan evaluation tool, was evaluated to be accurate for clinical implementation. For more complicated application, uncertainty in DVHs should be addressed with further investigation.

Keywords: plan evaluation, quality assurance, dose volume histogram, cumulative DVH, IAEA TRS-430

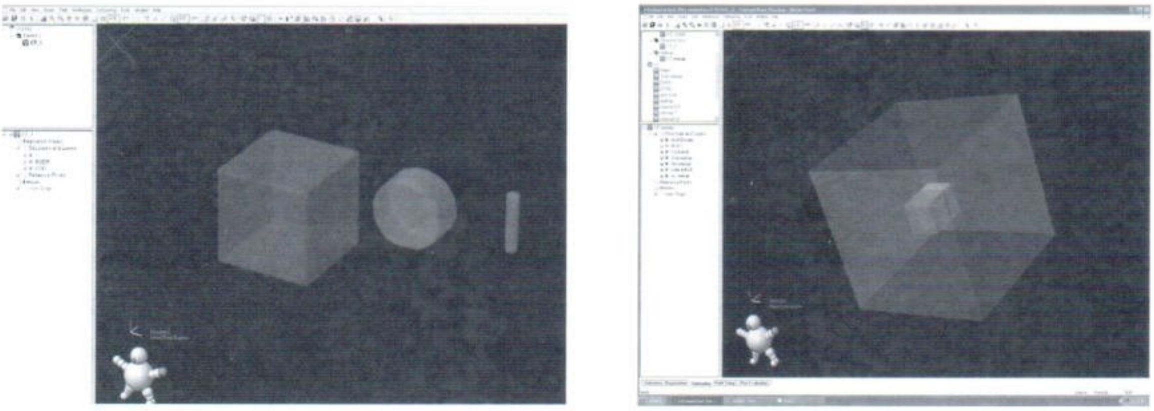
Introduction

Plan evaluations, using dose display and dose volume histogram, are found to be one of the most important tools in state-of-art in radiotherapy planning. Commonly, the standard display is the color-coded isodose lines or color wash which assigned color values corresponding to dose to each pixel on the display, paints the whole dose distribution in a transparent band of color overlaid on the grey scale 2D images. To perform plan optimization, dose verification and quality assurance testing, display as a "point dose" is additionally needed.[1] For analysis of treatment planning dose distributions, plan comparisons by dose volume histogram (DVH), which display how much of the volume of each structure receives how much dose, are also shown to be an efficient tool.[2-4] Currently, not only used for the plan evaluation, dose volume histogram is also being used as input data (DVH constraints) for intensity modulated radiation therapy (IMRT) planning. Hence, accuracy of the DVH performance should be verified.[5-7] In this study, investigation of the characteristics of dose display and cumulative DVH tools on Eclipse version 8.1 TPS was carried out through a series of test as recommended in the IAEA Technical Report Series no. 430 (TRS-430).[5]

Materials & Methods

A simple plan using a single field, 10 MV photon, 10x10 cm^2 with 100 cm SSD on a virtual water-like phantom (2 mm slice thickness, 30x30x30 cm^3 in size) with a prescribed dose 2 Gy at depth of 10 cm, was generated on Eclipse 8.1 TPS. Dose distribution was calculated using triple A algorithm and displayed as the isodose lines in all three axes: axial, sagittal and coronal plane. To determine an agreement of the isodose lines with the color wash and point doses, points were marked at the selected isodose level. Distances between the mark points and central axis beam were then measured and compared. In the experiments, isodose levels in the axial and sagittal plane from 150% to 50% and 100% to 5% in the coronal plane (with 5% interval) were examined. Consistency of dose display when transforming plan normalization from percent to absolute dose and varying total prescription dose from 2 Gy to be 50 Gy were also included in the investigation.

For cumulative DVH, the first aspect to be tested was the accuracy of calculated volume as determined by the system. Various size and shape perspex phantoms underwent CT scanner were exported to the Eclipse 8.1 TPS. The test objects, ranging in size from < 1 cc to > 10,000 cc, were selected to represent anatomical organs such as optic chiasm , eyeball and spinal cord. The smallest one used in the study was a perspex rod only 0.5 cm in diameter and 2.5 cm long , as shown in fig.1 (a). Using the threshold HU at -350 with no post-processing, auto-body contours were performed. Optimal window level was also adjusted until all the complete contours were obtained. Volume readings by the system were then recorded and compared with the known volume of the test objects. Ability of the Boolean logic to define compound structures was also verified. Two virtual structures with known size were created and used Boolean operators: AND, OR, XOR and SUB in the Eclipse 8.1 TPS to generate the overlap structures (fig.1b). Accuracy of the DVH calculations, when histogram dose bin were varied from 1 cGy to be 5 and 10 cGy, and dimension of calculation grid from routine 2.5 mm to be 1.25 and 5 to 10 mm, were



(a) (b)

Fig.1 Reconstructed volume from known dimension phantoms and compound structures using Boolean operators were generated on the Eclipse 8.1 TPS. The calculated volumes were then compared with the expected volume

studied. DVH statistical reports from two plans containing the same total dose, 2 Gy x 25 fractions and 50 Gy x 1 fraction, were exported as ASCII files. Then, agreement of the dose readings between these two plans were checked. DVHs based on either relative or absolute dose method were tested on two different plans, single-field and four-fields techniques. Report of the hot spot and cold spot dose which presented both on the isodose distribution display and dose statistics as Max dose, Min dose and Mean dose were compared with the expected values from the exported dose-volume data on ASCII files.

Results

Accuracy of the dose display tool

Consistency of the dose display tool on Eclipse 8.1 TPS was found to be acceptable. At the isodose levels from 150%-50% in the axial and sagittal plane, and from 100%-5% in the coronal plane, the majority of the deviations in all test cases were observed to be within ± 2 mm. Maximum deviation, about ± 2.8 mm, can be seen only at isodose level of 145% in the transverse plane on the test of isodose lines agreement with color wash and at 55% isodose level in the sagittal plane with relative and absolute dose test as shown in fig.2.

Cumulative Dose Volume Histograms Tool

Accuracy of the volume reading

Accuracy of Eclipse 8.1 TPS in determining the structure volumes was found to be satisfied. It is seen that, on the test objects (0.5-13824 cc), all deviations were generally about -2% (fig.3). Boolean compound volumes were also demonstrated to be accurate from - 0.03 to -3.39% (fig.4). All calculated volumes were underestimated due to the Eclipse's contouring software which smoothed the contour edge for the reconstructed volume.[15]

Effect of histogram dose bin width and calculation grid size on DVH calculations

Histogram dose bin width and calculation grid size are the main factors influencing the DVH

Fig.2 Consistency of the dose display, as isodose lines, color wash and point doses, as relative or absolute dose and when varying total doses in three axes, was found to be within ± 2 mm.

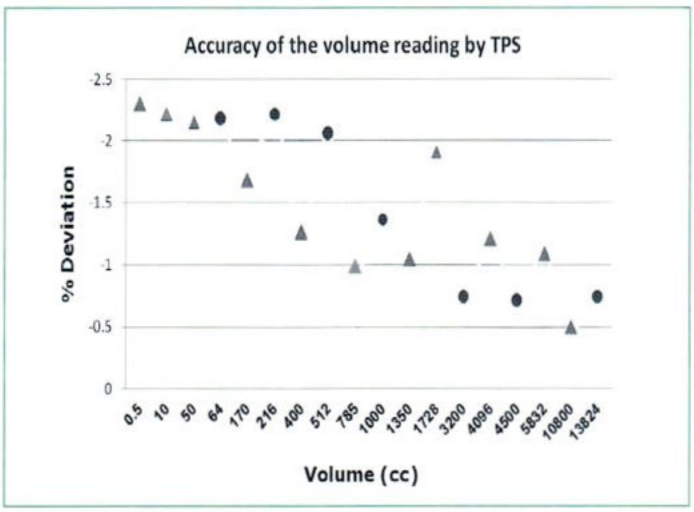


Fig.3 The percentage deviation between calculated and expected volume on Eclipse 8.1 TPS. Circle and triangle dots represent cube and cylindrical structures, respectively.

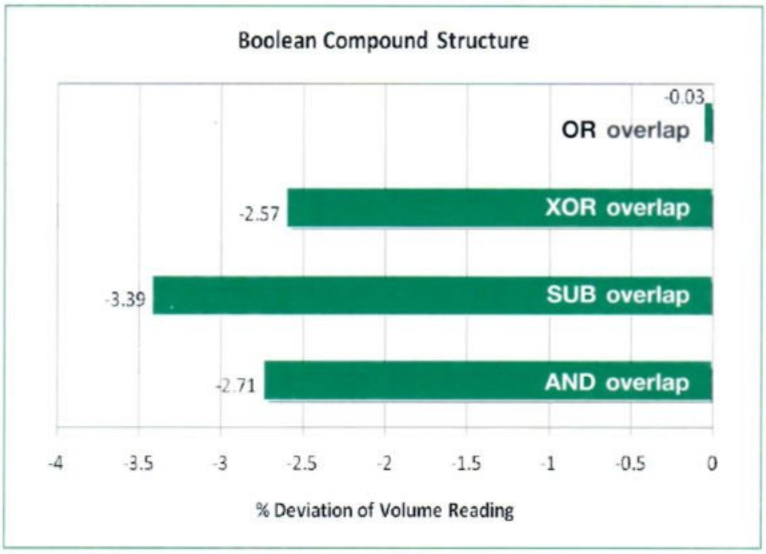
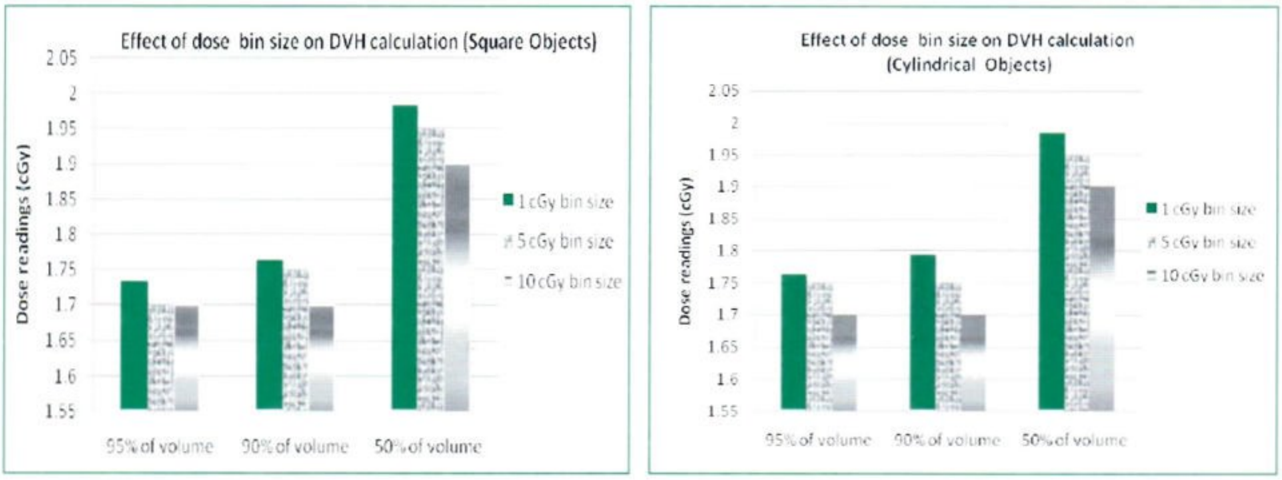


Fig.4 Uncertainty of the calculated volume found on Boolean compound structures when using AND, SUB, XOR and OR overlap operators

calculation. At the calculation grid 2.5 mm, when histogram dose bin was changed from 1 cGy to be 5 cGy, dose readings at 95%, 90% and 50% of the volume on cube and cylindrical objects were underestimated within 2%. The variations were increased to be 3-5% when histogram dose bin was set to be 10 cGy, as shown in fig.5.



(a) Cube objects

(b) Cylindrical objects

Fig.5 Variation of the dose readings on cube and cylindrical test objects when dose bin sizes at 1, 5 and 10 cGy were used for the DVH calculations

Table 1 Percent of dose difference between two plans, containing the same total dose, on cube and cylindrical objects, on the verification of the consistency of dose statistic report on cumulative DVH

Object	Volume Level	Dose Reading from DVH Statistical Report		
		2 Gy x 25	50Gyx1	% Difference
	Maximum	41.75	42.04	*0.69*
Cube	Minimum	58.25	58.1	*-0.26*
	Mean	49.5	49.6	*0.20*
	Maximum	42.25	42.61	*0.84*
Cylinder	Minimum	58.25	58.14	*-0.19*
	Mean	49.5	49.63	*0.26*

Table 2 Accuracy of the dose statistic readings when compared with the expected values on ASCII files

Object	Dose Level	Dose Readings(cGy)			% Difference from ASCII file data	
		Hot/Cold Spot	Dose Statistics	Exported Data	Hot/Cold Spot	Dose Statistics
Square	Maximum	2.32	2.32	2.33	*-0.43*	*-0.43*
	Minimum	1.69	1.69	1.69	*0.00*	*0*
	Mean	1.99	1.98	1.98	*0.51*	*0*
Cylinder	Maximum	2.32	2.32	2.33	*-0.43*	*-0.43*
	Minimum	1.71	1.68	1.69	*1.18*	*0.59*
	Mean	1.99	1.98	1.98	*0.51*	*0*

About the dimension of calculation grid, no significant difference of the cumulative DVHs computed from various calculation grids can be observed in this study. Dose readings on the DVH statistical reports were examined and all deviations on various test structures were found to be less than ±1%.

DVH statistical report and dose statistics

DVHs on two plans containing the same total dose, 2 Gy x 25 fractions and 50 Gy x 1 fraction, were exported as ASCII files and the results in Table 1 showed the consistency of DVH statistical report was within ±1%.

For dose statistics, comparison of the hot spot and cold spot dose on the isodose display and on the structure of plan (Max, Min, and Mean Dose) found them to be within 0-1.2% of the expected values from ASCII files as presented in Table 2.

DVH as relative and absolute dose mode

Relative and absolute dose DVHs on two different plans were demonstrated to perform properly. Results of the study showed the overall

Table 3 Comparisons of the dose readings from cumulative DVHs when displayed as relative and absolute dose mode on single-field and four-field technique plans

Object	Dose Level	Cumulative DVH					
		Single-field Technique			Four-field Technique		
		Relative	Absolute	% Difference	Relative	Absolute	% Difference
Cube	Maximum	2.32	2.33	*0.43*	2.01	2.03	*0.99*
	Minimum	1.68	1.67	*-0.60*	1.94	1.93	*-0.52*
	Mean	1.98	1.98	*0*	2	1.99	*-0.50*
Cylinder	Minimum	1.7	1.69	*-0.59*	1.94	1.93	*-0.52*
	Maximum	2.33	2.33	*0*	2.03	2.03	*0*
	Mean	1.98	1.98	*0*	1.99	1.99	*0*

deviations, at different dose levels, were less than 1%, as shown in Table 3.

Discussion & Conclusion

It is crucial for the overall quality of treatment that the characteristics of plan evaluation tools should be included in the assessment of a 3D treatment planning system. In our work, investigation of the accuracy of plan evaluation tools was proposed to complete the quality control process for the commercial TPS.

Many investigators had proposed the methods to evaluate the uncertainty in DVH calculations[9-13]. However, we found that the basic test protocol from IAEA Technical Report Series no. 430 was useful and convenient for our first step when examining the dose display and DVH capabilities and limitations.

To verify the accuracy of volume as determined by the Eclipse 8.1 TPS, we attempted to select test objects which closely represented the human anatomical organs. It was confirmed that, the system is able to provide an adequate accuracy of about 2%, even in the 0.5 cc rod structure which represents the optic chiasm.

Investigation of plan evaluation tools in this study was only performed by using the simple plan and homogeneous phantom. However, there was a report on quality assurance of DVHs in more complicated condition. DVHs in 9 IMRT planning from XKnife(tm) RT2 TPS, were verified with the Monte Carlo methods and the results indicated that the DVHs predicted by both methods were acceptable for the treatment execution[16].

In summary, the accuracy level of the Eclipse 8.1 plan evaluation tools are generally verified to be acceptable for use in the clinic. DVHs in the organs near high dose gradient or outside treatment beams are also recommended for further investigation.

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