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Script development for analysis of lung SBRT treatment plans and its impact on the radiotherapy workflow

Desenvolvimento de script para análise de planejamentos de SBRT pulmonar e seu impacto na rotina da radioterapia

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Abstract

Lung SBRT plan evaluation requires verification of dose-volume constraints and plan quality metrics, some of which depend on the planning target volume according to RTOG 0813 and RTOG 0915. This study developed and validated an Eclipse v13.6 script (Varian Medical Systems) to automate and standardize lung SBRT plan evaluation by calculating the conformity index, gradient index R50%, D2cm, and organ-at-risk dose constraints. The script performs linear interpolation when the reference value depends on PTV volume and presents the results through a color-coded evaluation interface. The numerical accuracy of the tool was validated by comparing script results with manual evaluation in 10 retrospective lung SBRT cases. Workflow impact was assessed by eight medical physicists who reviewed the same treatment plan with and without the script. All script-generated values were consistent with manual evaluation. The mean evaluation time decreased from 10.0 ± 2.6 min without the script to 3.8 ± 1.0 min with the script (paired t-test, $p < 0.001$). These results indicate that the tool can reduce repetitive work, standardize plan review, and contribute as an additional safety barrier in lung SBRT evaluation.

Keywords: Radiotherapy; Eclipse; ESAPI; Risk Management; Optimization; Lung SBRT.

1. Introduction

Radiotherapy is a highly complex modality of cancer treatment that relies on precise dose delivery to maximize tumor control while minimizing toxicity to surrounding healthy tissues (1). In this context, treatment planning plays a critical role in ensuring compliance with established dose constraints and institutional protocols.

1.1. Treatment Planning Systems

Treatment Planning Systems (TPS) allow quantitative evaluation of treatment plans through dose-volume histograms (DVHs), dose distributions, and automated clinical protocol tools. In Eclipse TPS (Varian Medical Systems, Palo Alto, CA), clinical protocols can automatically verify organ-at-risk (OAR) constraints and target coverage through color-coded objective tables. However, in widely used Eclipse versions, these tools have important limitations when dose constraints depend on algebraic relationships or variable thresholds associated with target absolute volume.

1.2. Lung SBRT

In a large part of routine cases, the dose constraints for organs at risk are absolute values established for each percentage of organ volume, independent of the size of the Planning Target Volume (PTV) (4). In these cases, it is possible to create clinical protocols in Eclipse to facilitate the plan analysis. According to RTOG 0813 and RTOG 0915 recommendations (5,6), several plan quality metrics vary as a function of PTV volume, including conformity index (CI), gradient index (R50%), and D2cm. Because Eclipse clinical protocols do not support linear interpolation between PTV-dependent values or algebraic ratios involving target volume, manual evaluation is commonly required for these cases.

Approximately 25 lung SBRT cases are treated annually at our institution, with an average of three candidate plans evaluated per case before treatment approval. Although this represents a specific subset of the total radiotherapy workload, these cases require careful review because small deviations in plan quality metrics or organ-at-risk constraints may have clinical relevance.

Figure 1 summarizes the RTOG-based plan quality criteria used in this study. The first column shows the PTV volume, and the remaining columns show the corresponding reference values for conformity, intermediate dose spillage, D2cm, and lung V20Gy.

PTV Volume (cc)	Ratio of Prescription Isodose Volume to the PTV Volume		Ratio of 50% Prescription Isodose Volume to the PTV Volume, $R_{50\%}$		Maximum Dose (in % of dose prescribed) @ 2 cm from PTV in Any Direction, D_{2cm} (Gy)		Percent of Lung Receiving 20 Gy Total or More, V_{20} (%)	
	Deviation		Deviation		Deviation		Deviation	
	None	Minor	None	Minor	None	Minor	None	Minor
1.8	<1.2	<1.5	<5.9	<7.5	<50.0	<57.0	<10	<15
3.8	<1.2	.<1.5	<5.5	<6.5	<50.0	<57.0	<10	<15
7.4	<1.2	<1.5	<5.1	<6.0	<50.0	<58.0	<10	<15
13.2	<1.2	<1.5	<4.7	<5.8	<50.0	<58.0	<10	<15
22.0	<1.2	<1.5	<4.5	<5.5	<54.0	<63.0	<10	<15
34.0	<1.2	<1.5	<4.3	<5.3	<58.0	<68.0	<10	<15
50.0	<1.2	<1.5	<4.0	<5.0	<62.0	<77.0	<10	<15
70.0	<1.2	<1.5	<3.5	<4.8	<66.0	<86.0	<10	<15
95.0	<1.2	<1.5	<3.3	<4.4	<70.0	<89.0	<10	<15
126.0	<1.2	<1.5	<3.1	<4.0	<73.0	>91.0	<10	<15
163.0	<1.2	<1.5	<2.9	<3.7	<77.0	>94.0	<10	<15

Figure 1. Lung SBRT plan quality criteria according to PTV volume, extracted from RTOG 0813 and RTOG 0915 protocols (5,6).

1.3. Scripting on the TPS

Eclipse provides the Eclipse Scripting Application Programming Interface (ESAPI), which allows access to treatment plan information and enables customized analyses within the clinical workflow. In older Eclipse versions, such as v13.6, scripting capabilities remain more limited than in recent releases, particularly regarding automation functionalities and database interaction. Nevertheless, many institutions still operate these versions in routine clinical practice (7,8).

Thus, the present study aimed to develop an Eclipse TPS–based script for automated evaluation of lung SBRT treatment plans according to RTOG recommendations, validate its computational accuracy, and assess its impact on clinical workflow efficiency within a large radiotherapy service.

2. Materials and Methods

2.1. Software Development and Workflow

The script was developed in C# using the ESAPI library implemented as a single-file plug-in within Eclipse TPS v13.6. It was designed to calculate plan quality metrics, apply RTOG-based criteria, perform linear interpolation when needed, and display the results in a structured table.

The plug-in was organized into separate helper routines for structure retrieval, metric evaluation, and table rendering, keeping the code modular within a single file. Each structure required for the analysis is retrieved from the active structure set by its identifier, and a verification routine confirms that all expected structures are present, interrupting execution with a message when one is missing to prevent partial or silent evaluation.

Absolute values regarding PTV coverage and OAR dose constraints are obtained from the DVH through the GetDoseAtVolume and GetVolumeAtDose command lines. Plan quality metrics are obtained directly from the DVH, the prescription and 50% prescription isodose volumes are computed on the body structure to derive CI and R50%, while D2cm is obtained from the maximum dose of the 2-cm ring structure. The PTV-volume–dependent references are implemented as a piecewise-linear lookup, in which the script identifies the two adjacent tabulated volumes (Figure 1) and interpolates linearly between their reference values, according to protocol recommendations. All expected interpolated values are displayed in the table for easy user interpretation.

The tool extracts basic patient and plan information, including patient name and ID, plan name, prescription dose, number of fractions, structure set name, target volume structure name and volume. It then calculates plan quality metrics and OAR dose constraints and displays the results in a color-coded table: green indicates protocol compliance, yellow indicates minor deviation within the accepted tolerance range, and red indicates protocol violation. This color scheme extends to all remaining tables in the script.

Since PTV nomenclature may vary between patients, the script uses the structure defined as the plan target volume within Eclipse for all target-based calculations. To evaluate D2cm, the script requires a previously generated ring structure positioned 2 cm from the PTV. Organs at risk are identified by standardized structure identifiers defined in the institutional naming template, which must be applied during contouring for the script to operate correctly.

When the PTV volume is below 1.8 cm³ or above 163 cm³, the script uses the nearest available reference values for evaluation. The corresponding result cells are highlighted in yellow to indicate that the evaluated volume is outside the protocol range.

The script automatically verifies dose-volume constraints for critical structures by retrieving the maximum point dose or volumetric doses for the OARs. Dose constraints were applied according to the prescribed fractionation scheme (1–5 fractions). For 1, 4 and 5 fraction treatments, the script evaluated both the RTOG protocol constraints (5,6) and additional constraints from the adopted literature (3,9). For 2 and 3 fractions, only literature-based constraints were considered. Minor deviation criteria defined by the RTOG protocols were preserved, whereas a 5% tolerance interval was additionally adopted for non-maximum dose constraints derived from the complementary literature.

2.2. Software validation

Ten retrospective lung SBRT cases treated at the institution were randomly selected for validation, covering all fractionation schemes (1 to 5 fractions). For each case, the values generated by the script were compared with those obtained manually from the treatment planning system, considering agreement when values matched within the displayed numerical precision. The comparison included plan quality metrics, PTV coverage, and organ-at-risk dose constraints.

The objective of this validation was to verify whether the script reproduced the same numerical values obtained during conventional manual review.

2.3. Optimization evaluation

To evaluate workflow impact, eight medical physicists with different levels of clinical experience reviewed the same lung SBRT treatment plan using two approaches: conventional manual evaluation and script-assisted evaluation.

During the manual review, the physicists assessed plan quality metrics, PTV coverage and organ-at-risk constraints according to the institutional SBRT workflow. In the subsequent script-assisted approach, the same analyses were performed after automated extraction, calculation, and visual classification by the tool.

The total evaluation time was measured by each physicist using a stopwatch, started at the beginning of the plan review task and stopped upon its completion, following the same timing instructions in both scenarios. The same treatment plan was used for all participants to reduce variability related to case complexity.

Data normality was assessed using the Shapiro–Wilk test. Manual and script-assisted evaluation times were compared using the paired t-test. Due to the small sample size, the paired Wilcoxon signed-rank test was additionally performed as a sensitivity analysis. A p-value lower than 0.05 was considered statistically significant.

2.4. Use of artificial intelligence tools

Artificial intelligence tools were used as auxiliary resources during manuscript preparation and software development, mainly for translation support, language revision, programming questions, and debugging assistance. All suggestions were reviewed by the authors, who remain fully responsible for the source code, numerical results, scientific content, and final manuscript.

2.5. Ethical Considerations and Data Privacy

This retrospective study was conducted using previously approved treatment plans and did not interfere with patient care or clinical decision-making. The project followed institutional quality assurance guidelines, was submitted to institutional ethics committee evaluation, and received approval according to local requirements.

To comply with the Brazilian General Data Protection Law (LGPD), all patient identifiers presented in figures and examples were anonymized. The software operates exclusively within the institution's secure network environment.

3. Results

After execution, the script displays the plan evaluation table in approximately 10 seconds. Figure 2 shows the output window generated by the finalized script.

In the 10 retrospective validation cases, all values generated by the script agreed with the values obtained by manual evaluation.

The mean total evaluation time decreased from 10.0 ± 2.6 min without the script to 3.8 ± 1.0 min with the script. Both datasets showed normal distribution according to the Shapiro–Wilk test ($p = 0.532$ and $p = 0.408$). Manual and script-assisted review times differed significantly in both the paired t-test ($p < 0.001$) and paired Wilcoxon test ($p = 0.014$).

4. Discussion

The script significantly reduced lung SBRT plan review time, with a mean absolute reduction of 6.2 min per plan (from 10.0 ± 2.6 min to 3.8 ± 1.0 min), corresponding to a mean reduction of 63 ± 28%.

Both the paired t-test and paired Wilcoxon test demonstrated statistically significant differences between manual and script-assisted review.

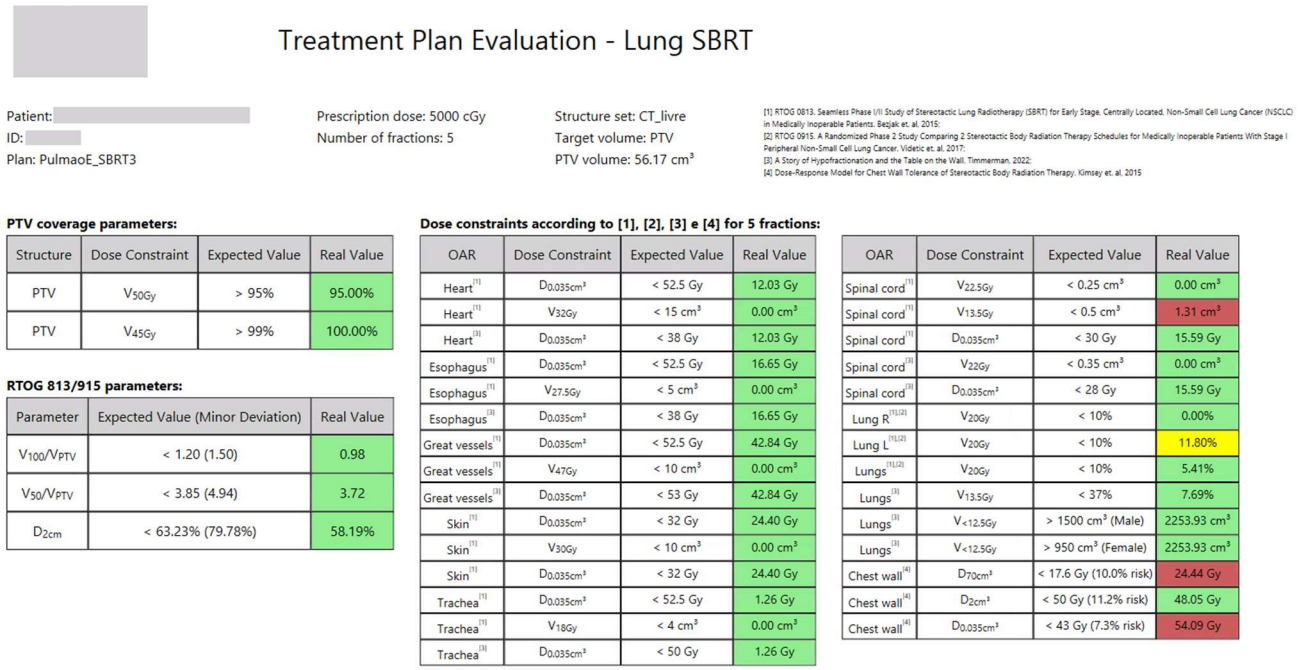
Although the sample size was limited, the paired design reduced the influence of interobserver variability in review time, since each physicist served as their own control.

At our institution, approximately 25 lung SBRT cases are treated annually, with an average of three candidate plans evaluated per case before treatment approval. Based on the observed mean reduction of 6.2 min per plan, this corresponds to approximately 8 hours of medical physicist review time saved per year dedicated to lung SBRT evaluation alone, excluding additional benefits related to standardization and reduction of repetitive manual calculations.

Beyond time reduction, the script may contribute to the standardization of plan review. By presenting the same metrics and constraints in a structured format, the tool reduces dependence on individual review habits and may reduce the risk of overlooking relevant parameters during routine review. However, the script should be understood as a support tool. It does not replace the physicist's clinical judgment or the complete plan review process.

One limitation is its dependence on standardized structure nomenclature. This issue was addressed through institutional naming templates implemented within Eclipse. Additionally, minor code adaptations may be required after TPS version updates to ensure compatibility across Eclipse releases.

Another potential benefit of the script is the rapid identification of parameters requiring attention. Yellow and red indicators allow immediate visualization of constraints that may require plan adjustment.



Treatment Plan Evaluation - Lung SBRT

Patient:
ID:
Plan: PulmaoE_SBRT3

Prescription dose: 5000 cGy
Number of fractions: 5

Structure set: CT_livre
Target volume: PTV
PTV volume: 56.17 cm³

[1] RTOG 0813. Seamless Phase I/II Study of Stereotactic Lung Radiotherapy (SBRT) for Early Stage, Centrally Located, Non-Small Cell Lung Cancer (NSCLC) in Medically Inoperable Patients. Bezjak et. al. 2015;
[2] RTOG 0915: A Randomized Phase 2 Study Comparing 2 Stereotactic Body Radiation Therapy Schedules for Medically Inoperable Patients With Stage I Peripheral Non-Small Cell Lung Cancer. Videtic et. al. 2017;
[3] A Story of Hypofractionation and the Table on the Wall. Timmerman, 2022;
[4] Dose-Response Model for Chest Wall Tolerance of Stereotactic Body Radiation Therapy. Kimsey et. al. 2015

PTV coverage parameters:

Structure	Dose Constraint	Expected Value	Real Value
PTV	V_{50Gy}	> 95%	95.00%
PTV	V_{45Gy}	> 99%	100.00%

RTOG 813/915 parameters:

Parameter	Expected Value (Minor Deviation)	Real Value
V_{100}/V_{PTV}	< 1.20 (1.50)	0.98
V_{50}/V_{PTV}	< 3.85 (4.94)	3.72
D_{2cm}	< 63.23% (79.78%)	58.19%

Dose constraints according to [1], [2], [3] e [4] for 5 fractions:

OAR	Dose Constraint	Expected Value	Real Value
Heart[1]	$D_{0.035cm^3}$	< 52.5 Gy	12.03 Gy
Heart[1]	V_{32Gy}	< 15 cm^3	0.00 cm^3
Heart[3]	$D_{0.035cm^3}$	< 38 Gy	12.03 Gy
Esophagus[1]	$D_{0.035cm^3}$	< 52.5 Gy	16.65 Gy
Esophagus[1]	$V_{27.5Gy}$	< 5 cm^3	0.00 cm^3
Esophagus[3]	$D_{0.035cm^3}$	< 38 Gy	16.65 Gy
Great vessels[1]	$D_{0.035cm^3}$	< 52.5 Gy	42.84 Gy
Great vessels[1]	V_{47Gy}	< 10 cm^3	0.00 cm^3
Great vessels[3]	$D_{0.035cm^3}$	< 53 Gy	42.84 Gy
Skin[1]	$D_{0.035cm^3}$	< 32 Gy	24.40 Gy
Skin[1]	V_{30Gy}	< 10 cm^3	0.00 cm^3
Skin[1]	$D_{0.035cm^3}$	< 32 Gy	24.40 Gy
Trachea[1]	$D_{0.035cm^3}$	< 52.5 Gy	1.26 Gy
Trachea[1]	V_{18Gy}	< 4 cm^3	0.00 cm^3
Trachea[3]	$D_{0.035cm^3}$	< 50 Gy	1.26 Gy

OAR	Dose Constraint	Expected Value	Real Value
Spinal cord[1]	$V_{22.5Gy}$	< 0.25 cm^3	0.00 cm^3
Spinal cord[1]	$V_{13.5Gy}$	< 0.5 cm^3	1.31 cm^3
Spinal cord[1]	$D_{0.035cm^3}$	< 30 Gy	15.59 Gy
Spinal cord[3]	V_{22Gy}	< 0.35 cm^3	0.00 cm^3
Spinal cord[3]	$D_{0.035cm^3}$	< 28 Gy	15.59 Gy
Lung R[1],[2]	V_{20Gy}	< 10%	0.00%
Lung L[1],[2]	V_{20Gy}	< 10%	11.80%
Lungs[1],[2]	V_{20Gy}	< 10%	5.41%
Lungs[3]	$V_{13.5Gy}$	< 37%	7.69%
Lungs[3]	$V_{<12.5Gy}$	> 1500 cm^3 (Male)	2253.93 cm^3
Lungs[3]	$V_{<12.5Gy}$	> 950 cm^3 (Female)	2253.93 cm^3
Chest wall[4]	D_{70cm^3}	< 17.6 Gy (10.0% risk)	24.44 Gy
Chest wall[4]	D_{2cm^3}	< 50 Gy (11.2% risk)	48.05 Gy
Chest wall[4]	$D_{0.035cm^3}$	< 43 Gy (7.3% risk)	54.09 Gy

Figure 2. Window displayed by the treatment plan evaluation script.

Although this study did not directly evaluate dosimetric improvements, the tool may support more consistent plan quality review (10,11).

Validation was retrospective and limited to a single institution. Workflow analysis was based on one lung SBRT treatment plan and may not reflect the full variability of clinical cases. Because the same physicists performed both manual and script-assisted reviews, a learning effect cannot be excluded. Therefore, the observed reduction in review time should be interpreted within the evaluated workflow context. Future studies should include larger cohorts, randomized review order, and multicenter validation.

The use of interpolated RTOG values is one of the most relevant aspects of the script. In lung SBRT plan review, manual interpolation between tabulated protocol values may be labor-intensive and susceptible to inconsistencies or oversight during routine evaluation. By automatically performing these calculations, the script standardizes this step of the review process and allows protocol-based constraints to be evaluated more consistently and efficiently.

The development of clinical scripts also highlights the importance of programming skills in medical physics. Tools that reduce repetitive calculations and manual verification tasks may allow physicists to spend more time on patient-specific QA review, equipment quality assurance, commissioning, protocol development, staff training, discussion of complex cases, research conduction and workflow optimization.

Radiotherapy is increasingly transitioning toward automation-driven workflows, requiring Medical Physics departments to actively support the development, validation, and safe implementation of clinical scripting tools. As newer versions of Eclipse expand automation capabilities, appropriate and validated use of these tools becomes progressively more important within the treatment planning process.

Script development requires dedicated time for testing and validation. In this study, validation included manual verification of the calculated metrics, retrospective comparison in 10 clinical cases, and assessment of tool performance before clinical use. The overall estimated development and validation process was approximately four months, while maintaining routine clinical and educational activities in the institution.

5. Conclusions

The Eclipse script developed in this study enabled automated evaluation of lung SBRT treatment plans according to RTOG 0813 and RTOG 0915 recommendations, including the calculation of conformity index, R50%, D2cm, and organ-at-risk dose constraints. In the retrospective cases analyzed, all script-generated values were consistent with manual evaluation, supporting the numerical accuracy of the tool within the evaluated clinical workflow.

The script significantly reduced plan review time, with a mean decrease of 63% compared to conventional manual evaluation (from 10.0 ± 2.6 min to 3.8 ± 1.0 min; $p < 0.001$).

By consolidating PTV-volume-dependent metrics, organ-at-risk constraints, PTV coverage, and visual alerts within a single interface, the script enhances the standardization of the peer-review process. Its clinical use, however, depends on correct structure selection, standardized nomenclature, and local validation.

These findings support the broader adoption of clinical scripting solutions in radiotherapy services operating with earlier Eclipse releases, demonstrating that meaningful improvements in efficiency and

standardization are achievable even within constrained development environments.

6. Data availability Statement

The source code of the developed Eclipse script is not publicly deposited in a repository but is available upon reasonable request to the corresponding author. Local adaptation, commissioning, and independent validation are required before clinical use.

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