VMAT TBI And CSI Automated Planning Optimization Loop Script User Guide

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(Revised September 22, 2023)

Contents

1 Disclaimers

- All code is provided free of charge under the MIT open-source license. You are welcome to use the code as is or modify it as you see fit. Should you use this code please:
  - Mention where the code came from
  - Don't claim you wrote it
  - Understand, **I don't claim this code works and I'm not responsible if it doesn't**
- All code was developed and tested on v15.6 of Varian Eclipse^{TM} (Palo Alto, CA)

2 Current script versions

The below guide is valid and accurate for script versions:
Preparation Script: 1.1.*
Optimization Loop: 1.1.*

3 Publications

N. Kovalchuk and E. Simiele, L. Skinner, Y. Yang, N. Howell, J. Lewis, C. Hui, E. Blomain, R. Hoppe, and S. Hiniker, "The Stanford Volumetric Modulated Arc Therapy Total Body Irradiation Technique," *Practical Radiation Oncology*, 12:245-258 (2022)

C. Marquez, C. Hui, E. Simiele, E. Blomain, J. Oh, A. Bertaina, O. Klein, D. Shyr, A. Jiang, R. Hoppe, N. Kovalchuk, S. Hiniker, "Volumetric modulated arc therapy total body irradiation in pediatric and adolescent/young adult patients undergoing stem cell transplantation: Early outcomes and toxicities," *Pediatric Blood & Cancer*, 69e29689 (2022)

E. Simiele et al., "A Step Toward Making VMAT TBI More Prevalent: Automating the Treatment Planning Process." Practical radiation oncology, S1879-8500(21)00061-8 (2021), doi:10.1016/j.prro.2021.02.010

4 Introduction

The purpose of this document is to provide guidance for the VMAT TBI And CSI autoplanning scripts. Please take a second to read the disclaimers if you haven't done so already. The code contained within this project was built on the ideas and framework of the original VMAT TBI autoplanning code that was released in 2021. However, numerous extensions and features specifically tailered to VMAT CSI were incorporated such as support generating and sequential optimizing sequential boost CSI plans. The code has been rewritten to be more

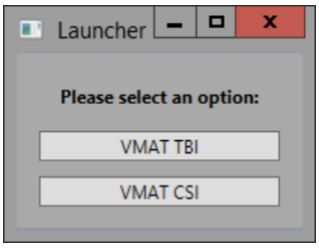


Figure 1: Launcher script user interface (UI)

maintainable, modular, and extenable. The autoplanning process using this code is broken into two parts: preparation and optimization. By breaking the process into two distinct sections, the planner has a chance to review the generated tuning/optimization structures, the created plan(s), the isocenter and beam placement, and assigned optimization objectives prior to the optimization loop. Should a problem be discovered, the planner can easily fix the issue or rerun the preparation script rather than losing time optimizing plan(s) with a sub-optimal setup. The optimization loop script is solely responsible for automating the optimization process where multiple optimizations are performed. For instructions on how to download and install the autoplanning code, please refer to the 'Install_and_run_guide.pdf' document.

This help guide focuses on the details of the optimization loop script. This script is intended to run successive optimizations without planner intervention. Upon launch and patient selection (done implicitly when run over citrix), the script will pull the logs from the preparation script and populate the relevant information in the user interface (UI). In addition to pulling the logs, the script determines if a template plan was used during preparation. If so, the information from the selected template plan is used to set various configuration parameters regarding the optimization loop run, specifically, which information should be pulled and reported by the script. The details of the plan templates were discussed in the preparation script and interested readers should refer to that guide for a complete discussion on plan template files and how they work with the scripts. This script is designed to work with both VMAT-TBI and VMAT-CSI plans. For VMAT-CSI plans, the script can handle single plan CSI (e.g., initial only, 12 Gy in 6 fractions) or sequential boost CSI.

5 Launcher Script

- All scripts in this project interfact with a launcher script to allow of the user to easily launch the script from within Eclipse
  - **This is the only way to launch the scripts from within Eclipse**
  - This launcher script can also be used to launch the optimization loop script if a plan was previously created using the preparation script
- To run the CSI autoplanning script, open a patient structure set in external beam planning and run the 'LaunchVMATTBICSIAutoPlan.cs' script (located in the /bin

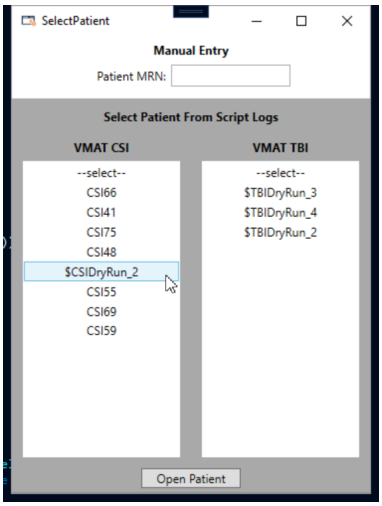


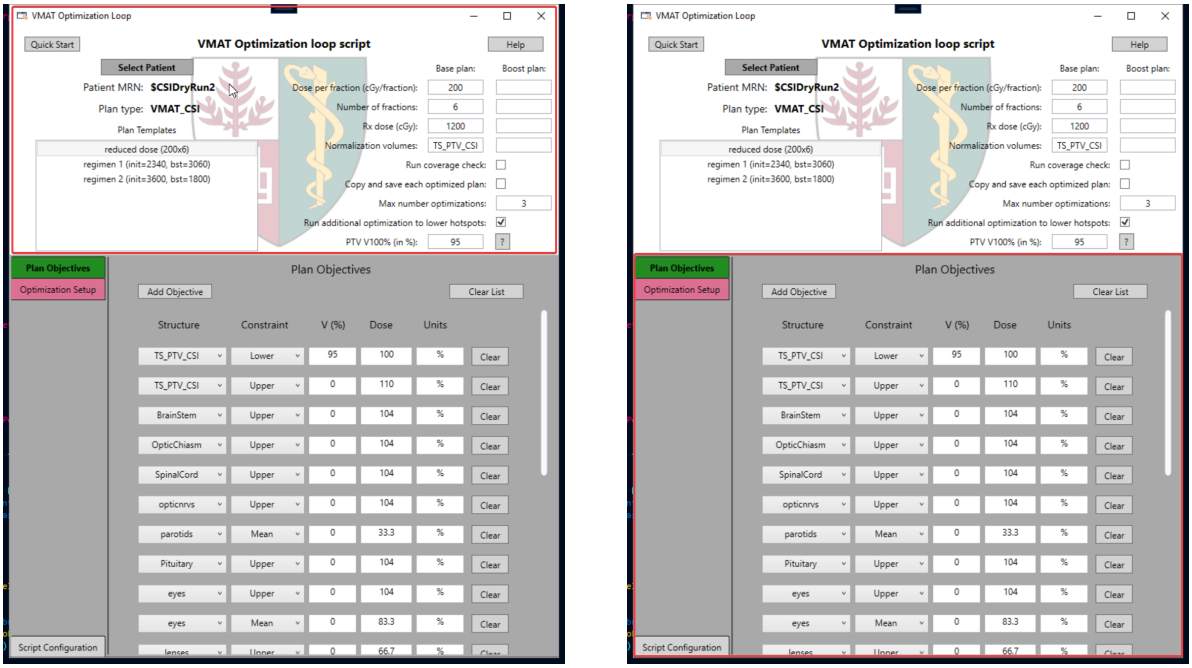
Figure 2: Patient selection UI

folder of the VMAT-TBI-CSI code)

- The user interface for the launcher script is shown in Figure 1
- If the launcher script detects a plan as been prepared by the preparation script and is ready for optimization, a third button will appear below VMAT CSI and launches the optimization loop script

6 Patient Selection

- If the optimization loop script is NOT launched from Eclipse, then the user will need to manually select a patient for optimization
  - If the script is launched from Eclipse, all the relevant information is passed to the optimization loop script and this step is skipped
- To assist with this process, a simple UI will appear upon launching the optimization loop script (Figure 2)
- In Figure 2, the user can easily see the recent patients (MRNs) that have been run through the preparation script for both VMAT-TBI and VMAT-CSI
- The user can select one of these patient MRNs and hit Open Patient button to load the patient into the optimization loop script
- If the patient of interest is NOT shown in the recent patient list from the script logs, the user can manually enter the patient MRN at the top of Figure 2
- Hitting Open Patient at the button will load the patient into the optimization loop script



(a) (b)

Figure 3: a) The header and b) body of the auto-planning optimization loop script. In the header, the user can select the patient that should be run, the plan template that should be used, if a target coverage check should be performed, if the script should create a copy of each optimized plan for review, the maximum number of optimizations, if the script should run one additional optimization to lower hotspots, and the default normalization to achieve the requested PTV coverage. If the user is confused or doesn't understand what certain warning messages mean, they can hit the help button, which will open this guide. In the body, the user can perform review and adjust (if necessary) the plan objectives and optimization constraints for this run of the optimization loop.

7 Basic Information, UI, and Operation

- If launched from Eclipse, select 'Launch Optimization Loop' from the Launcher UI
- If launched directly from the executable outside of Eclipse, select a patient from the Select Patient UI
- The main auto-planning optimization loop script user interface (UI) is shown in Figure 3
- The UI in this script was designed to be relatively rigid where the user can review and make adjustments to the plan optimization parameters
- **The plan prescriptions cannot be modified in this program!**
- **The normalization volumes cannot be modified in this program!**
- The global parameters, including patient Id, plan type, Rx, normalization volume, and optimization configuration parameters are shown in the upper part of the UI (Figure 3a)
- In the global parameters, the user can:
  - choose if to run a coverage check before the optimization loop
    - This is an optimization with no intermediate dose where all optimization objective priorities are set to zero except for the target objective (i.e., if we are jsut trying to cover the target, how well can we do it?). If the global hotspot is $> 140\%$, that indicates that the target is being undercovered
    - In general, this will only be useful for VMAT TBI and not VMAT CSI
  - Adjust any of the optimization constraints, which were read from the plan(s) generated by the preparation script
  - Adjust the maximum number of optimizations that will be performed
  - Choose to perform an additional optimization to reduce the plan hotspots
    - **This optimization is performed <u>AFTER</u> the main optimization loop**
  - Select whether the script should save each optimized plan. This option copies the resulting plan from each optimization iteration and saves it to the course containing the original plan with the name "opt itr <count>" where <count> is the current optimization iteration
    - This is useful to see how the optimization is progressing with each plan. In addition, it also allows the planner to choose from multiple plans to do final adjustments
- The planning objectives and optimization constraints can be reviewed and adjusted in the body of the UI as shown in Figure 3b

- The Script Configuration tab functions similarly to the Script Configuration tab on the preparation script and will not be discussed here
- To assist the user in navigating the user interface, the tabs change color depending on which action should be performed next
  - Red –> items require attention
  - Green –> items have been completed
- For TBI cases, if you elected to include additional flash in the optimization (from the preparation script), you DON'T need to do anything. The script automatically detects if flash was included and will make adjustments accordingly
- Once satisfied with the constraints, hit the 'Confirm and Begin Optimization' button to start the optimization loop

8 Optimization Loop

- The optimization loop progress window UI is shown in Figure 4. The UI was designed to inform the user of the progress of the optimization loop and how the program is adjusting the optimization constraints after each iteration
- The status of the program is represented as 'Running', 'Canceling', 'Aborted', 'Failed', or 'Finished' as shown in the text box in the bottom left of Figure 4.
- The user has the option the abort the optimization loop using the 'Abort' button in the bottom left of Figure 4. This will tell the program the user wants to stop the optimization loop
  - **NOTE: THE PROGRAM WILL (LIKELY) NOT STOP IMMEDIATELY WHEN YOU HIT THE 'ABORT' BUTTON! THIS IS BECAUSE THE PROGRAM IS TIED UP IN PERFORMING A COMPUTATIONALLY EXPENSIVE TASK IN ECLIPSE (e.g., DOSE CALCULATION) AND THERE IS NO SAFE WAY OF TERMINATING THAT PROCESS IN ESAPI**
  - **BE PATIENT! THE PROGRAM IS ROUTINELY CHECKING IF THE USER WANTS TO STOP THE OPTIMIZATION LOOP AND WILL TERMINATE WHEN AN ACCEPTABLE STOPPING POINT HAS BEEN REACHED**
- NOTE: DO NOT try to close the window while the optimization loop is running! This will not terminate the optimization loop immediately. A safeguard (basically, a bunch of annoying pop up windows) has been implemented to prevent the user from closing the window before the optimization loop has finished or been safely aborted

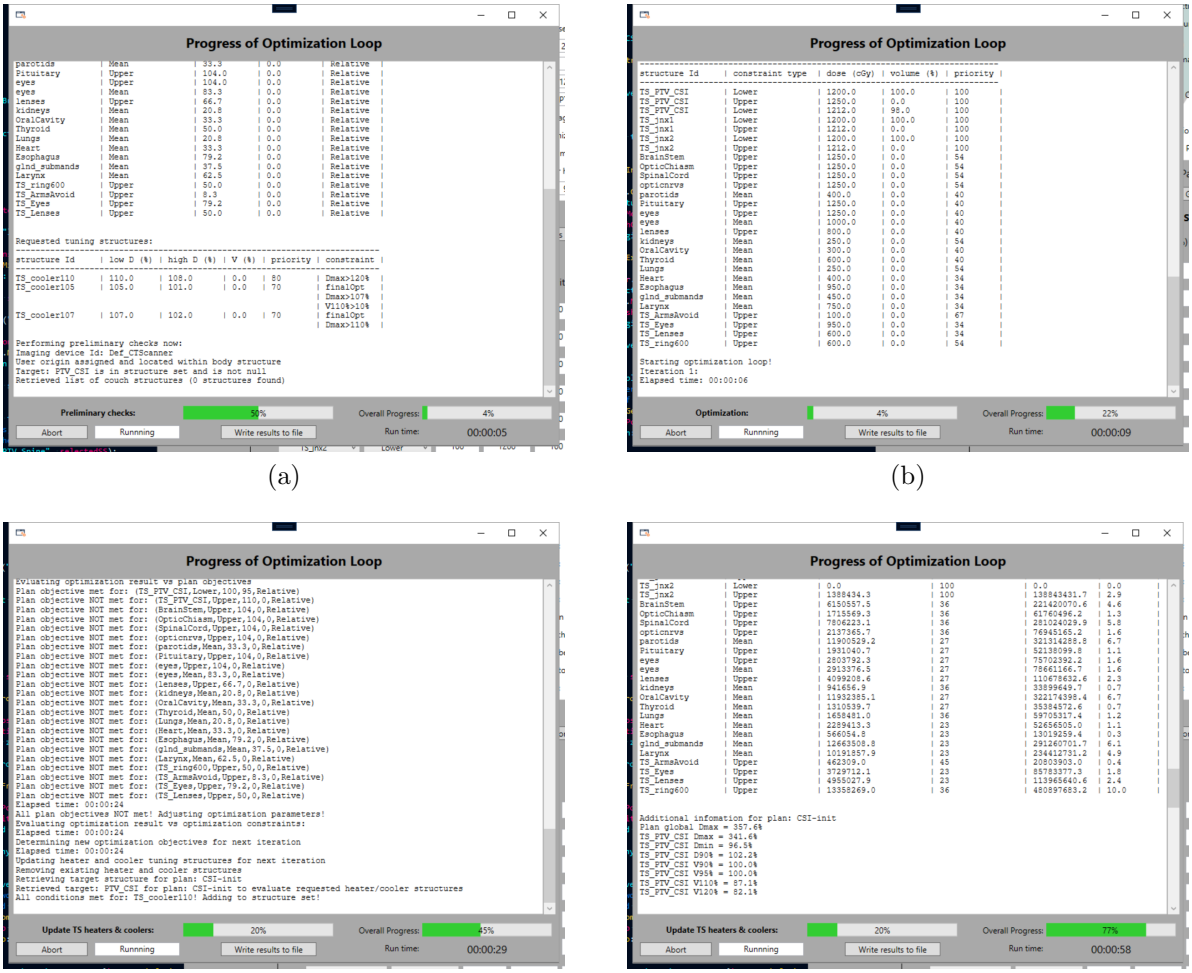


Figure 4: Optimization loop progress window UI. a-d) illustrate the various stages of an optimization loop run for a CSI initial-only case. The current task and progress are illustrated by the label and progress bar at the bottom left and center of the UI. The overall progress and elapsed run time of the optimization loop is shown at the bottom right of the UI. The user can request to abort the optimization loop using the 'Abort' button. The text in the UI can be immediately dumped to a text file for use by the user.

- The GUI window can be closed only when the program status is 'Aborted', 'Failed', or 'Finished'
- The current task and progress of the current task is shown by the label and progress bar at the bottom of the UI
- The overall progress of the optimization loop routine is shown in the progress bar in the bottom right of Figure 4
- At any time, the user can write the displayed text output to a text file at a location of their choosing by hitting the 'Write results to file'. Note, this will overwrite an existing file

8.1 Program Flow

8.2 Preliminary Checks and Coverage Check

- Once the 'Confirm and Begin Optimization' button is hit, the program reads the configuration settings, planning objectives, and optimization constraints
- Preliminary checks are then performed including if the user origin was set, are the isocenter positions set correctly (i.e., all z-positions are rounded-off, x/y positions = 0.0, etc.), etc.
- The program also checks if a couch structure is present. If not, it will ask the user if they want to continue anyway or stop and insert the couch
- A new feature included with the optimization loop script is the ability to automatically detect popup warning windows from Eclipse, an close them
  - This eliminates the need for cropping the couch structures from the first and last slices of the CT scan (present in the first iteration of the VMAT-TBI autoplanning code)
- If all the preliminary checks pass, the optimization loop will commence
- If you elected to run a coverage check, the script will then perform the coverage check by zero-ing the optimization constraints for all OARs and running an optimization with no intermediate dose. Following the optimization, dose is calculated and the plan is normalized to achieve the requested target coverage to the normalization volume
- If the hotspot in the resulting plan is $> 140\%$, a warning message will be printed to the user saying the beam arrangement is likely under-covering the target volume (at this point, you should consider stopping the optimization and adjusting the beam orientations)
  - The plan global hotspot is used as a surrogate measure of the quality of target coverage

- Following the coverage check, the OAR objective priorities are changed to a fraction of the priority specified by the user for each OAR (specifically, 2/3 of the specified priority)
- The progression of the optimization loop varies based on the type of case being optimized: TBI or CSI
  - The case type can be further divided for CSI: initial-only or sequential boost CSI
- The optimization loop program flow is described in detail for each of these cases in the following sections

8.3 TBI cases

- The optimization loop is then executed. Each optimization loop iteration consists of:
  - A VMAT optimization with intermediate dose switched off
  - A dose calculation following the optimization
  - Normalization of the plan dose to deliver the requested target coverage to the normalization volume
  - Plan evaluation to determine if the plan goals were met
    - If the plan goals were met, the optimization loop is broken.
    - If the goals were not met, the script reviews the relative cost associated with each optimization object and determines how to adjust each optimization parameter
  - Cooler and heater tuning structures are generated after each loop iteration to try and reduce hotspots and improve target coverage, respectively
    - The requested heater and cooler structures can be specified in the plan template .ini files
    - In addition to requesting the dose levels and priorities, the user can also specify the conditions that must be satisified for the script to generate the heater/cooler structure
  - The optimization parameters for the cooler and heater tuning structures and the updated optimization parameters for the target and OAR structures are assigned to the plan
  - If the user elected to save the resulting plan from each optimization, the resulting normalized plan from this iteration is copied and saved to the VMAT CSI course
    - NOTE: If the user did NOT elect to run one additional optimization, the number of "opt itr" plans will be one less than the number of requested optimization iterations. This avoids having two copies of the same plan from the final iteration of the optimization loop

  - The next iteration of the optimization loop is started

- The number of loop iterations requested by the user (Figure 3) are performed
- If the user requested an additional optimization to reduce the plan hotspots (Figure 3), the tuning structure segmenting the high dose regions (e.g., dose > 110% Rx dose) from the final optimization iteration is obtained and:
  - The priority for this objective is increased to the maximum priority in the list of optimization objectives
- The additional optimization is then performed by continuing the previous optimzation using the previously calculated dose as the intermediate dose. The optimization should start from MR3 or MR4 depending on the TPS configuration
- Once the number of iterations has been reached and the additional optimization performed (if requested), the optimization loop will evaluate if flash structures were added to the structure set with the preparation script. If so, the optimization script will then:
  - Wipe the calculated dose
  - Un-assign the HU to the bolus_flash structure (i.e., treated as air)
  - Recalculate dose using the optimized MLC pattern
  - Normalize the plan to achieve the requested target coverage for the non-flash VMAT target structure
- Once the script finishes, the user is informed the optimization loop is complete and the results have been saved to the Aria database
- You can now open the patient in Eclipse and evaluate the quality of the resulting plan(s). If you are completely unhappy, you can reset the dose calculation matrix, delete the MLCs for each field, and try again with different parameters

8.4 Initial-only CSI cases

- The flow of the initial-only CSI cases identical to the TBI cases except the script will not look for flash structures following completion of the optimization loop

8.5 Sequential boost CSI cases

- The flow of sequential boost CSI cases is similar to initial-only cases, however, the script must now optimize the quality of two plans that depend on each other
- All optimizations are performed with intermediate dose switched off to increase efficiency (through testing we found that using intermediate dose for these cases really doesn't improve plan quality)

- Following optimization, dose calculation, and normalization of the initial and boost CSI plans, a plan sum is created
- Since no method exists in v15.6 of ESAPI to create a plan sum, a custom method was developed to create a plan sum
  - The Evaluation Dose method was utilized in Eclipse to "build" a plan sum
- Following creation of the plan sum, the summed dose distribution is evaluated against the planning objectives
- If all of the planning objectives are met, the optimization loop is terminated
- If not, the DVH of each plan is then compared against the requested optimization objectives and adjustments are made to the optimization constraints for each plan
- The next iteration of the optimization loop starts
- Following the maximum number of iterations, an additional optimization is performed for both plans is the user requested one additional optimization to lower hot spots
- If the user requested one additional optimization to lower hot spots, following the additional optimization, the hotspot in the initial CSI plan is evlauted
  - If the hotspot is $> 110\%$, a high-priority cooler structure segmenting the 107% dose regions is added and one additional optimization is performed on the INITIAL CSI plan
  - Following dose calculation, a new plan sum is generated

9 Script Configuration

- The preparation script was designed to read multiple .ini configuration files upon launch. These include:
  - A log configuration file
  - General configuration settings specific to the preparation script
  - Plan templates
- The use of these configuration files reduces the number of times an end user would need to modify the underlying code and recompile
- The log configuration file **MUST** be named 'log_configuration.ini'
- The general configuration file **MUST** be named 'CSI_optimization_config.ini' for CSI planning and 'TBI_optimization_config.ini' for TBI planning

- Both the log configuration file and the general configuration file **MUST** be placed in the /bin/configuration directory
  - This is performed automatically when compiling the code (the configuration files are part of the Visual Studio projects)
- The plan template files **MUST** be placed in the /bin/templates/CSI and /bin/templates/TBI directories
  - This is performed automatically when compiling the code (the plan template files are part of the Visual Studio projects)
- **NOTE: THERE CAN BE NO EMPTY LINES IN THESE FILES! THIS WILL CAUSE PARSING TO FAIL!**
- Comments can be added to the configuration files using the '%' character (similar to MATLAB or LaTeX)
- The supplied configuration files already list all available options that can be modified in the preparation script
- As illustrated above, configuration settings in the .ini file are of two types: single parameters and array parameters
  - single parameter type: parameter=value
  - array parameter type: add array parameter{value 1,value 2,value 3,...}
- Array parameters will always contain the assigned values between the '{}' braces
- **IMPORTANT:**
  - For single parameter types, there can be no spaces between the parameter, '=' character, and assigned value!
  - For array parameter types, there can be no spaces between values (i.e., no space between value n, ',' character, and value n+1)!
- Should the current configuration settings not be appropriate for this patient, the user has the option to load a different configuration .ini file

10 Known issues and bugs

The following are known issues with the script:

- None as of now

Known limitations in ESAPI v15.6 (limits the functionality of the script):

- It is not possible to set the target volume ID in a newly created plan in ESAPI v15.5 (fixed in v16.0)
- It is not possible to assign a primary reference point in a newly created plan in ESAPI v15.6. A primary reference point is automatically created and can't be changed (fixed in v16.0)
- It is not possible to create setup fields for plans in ESAPI v15.5 (fixed in v16.0)
- It is not possible to create or remove plan sums from the script in ESAPI v15.5 (fixed in v16.0)
- It is not possible to assign plan goals for plans in ESAPI v15.5
- It is not possible to remove the automatic normal tissue objective (NTO) in optimization in ESAPI v15.5. However, the script does not remove the NTO, but assigns the priority to 0
- It is not possible to set a MU objective for optimization in ESAPI v15.5

Appendix A

Table I: Targets for reduced dose regimen (R_x=1200 cGy).

Target Id	**Total R_x (cGy)**	**Plan Id**
PTV_CSI	1200	CSI-Init

Table II: Tuning structures to be generated for reduced dose regimen (R_x=1200 cGy).

TS Structure Id
TS_Eyes
TS_Lenses
TS_ArmsAvoid

Table III: Default Rings for reduced dose regimen (R_x=1200 cGy).

Target Id	**Margin from target (cm)**	**Ring thickness**	**Dose level (cGy)**
PTV_CSI	1.5	2.0	600

Table IV: Planning goals for reduced dose regimen (R_x=1200 cGy).

Structure	**Dosimetric parameter**	**Limit**
PTV_CSI	V95% >=	100%
	D_{max} <=	110%
BrainStem	D_{max} <=	104%
OpticChiasm	D_{max} <=	104%
SpinalCord	D_{max} <=	104%
OpticNrvs	D_{max} <=	104%
Cochleas	D_{max} <=	104%
	D_{mean} <=	100%
Parotids	D_{mean} <=	33.3%
Pituitary	D_{max} <=	104%
Eyes	D_{max} <=	104%
	D_{mean} <=	83.3%
Lenses	D_{max} <=	66.7%
Kidneys	D_{mean} <=	20.8%
Ovaries	D_{mean} <=	10.0%
	D_{max} <=	20.8%
OralCavity	D_{mean} <=	33.3%
Thyroid	D_{mean} <=	50.0%
Lungs	D_{mean} <=	20.8%
Heart	D_{mean} <=	33.3%
Esophagus	D_{mean} <=	79.2%
Glnd_submands	D_{mean} <=	37.5%
Larynx	D_{mean} <=	62.5%
TS_ring600	D_{max} <=	50.0%
TS_ArmsAvoid	D_{max} <=	8.3%
TS_Eyes	D_{max} <=	79.2%
TS_Lenses	D_{max} <=	50.0%

Table V: Optimization constraints for reduced dose regimen (R_x=1200 cGy).

Structure	**Optimization constraint**	**Priority**
PTV_CSI	V100% >= 1200 cGy	100
	D_{max} <= 1250 cGy	100
	D98% <= 1212 cGy	100
BrainStem	D_{max} <= 1250 cGy	80
OpticChiasm	D_{max} <= 1250 cGy	80
SpinalCord	D_{max} <= 1250 cGy	80
OpticNrvs	D_{max} <= 1250 cGy	80
Cochleas	D_{max} <= 1250 cGy	60
	D_{mean} <= 1200 cGy	60
Parotids	D_{mean} <= 400 cGy	60
Pituitary	D_{max} <= 1250 cGy	60
Eyes	D_{max} <= 1250 cGy	60
	D_{mean} <= 1000 cGy	60
Lenses	D_{max} <= 800 cGy	60
Kidneys	D_{mean} <= 250 cGy	80
Ovaries	D_{mean} <= 120 cGy	60
	D_{max} <= 250 cGy	60
OralCavity	D_{mean} <= 300 cGy	60
Thyroid	D_{mean} <= 600 cGy	60
Lungs	D_{mean} <= 250 cGy	80
Heart	D_{mean} <= 400 cGy	50
Esophagus	D_{mean} <= 950 cGy	50
Glnd_submands	D_{mean} <= 450 cGy	50
Larynx	D_{mean} <= 750 cGy	50
TS_ring600	D_{max} <= 600 cGy	80
TS_ArmsAvoid	D_{max} <= 100 cGy	100
TS_Eyes	D_{max} <= 950 cGy	50
TS_Lenses	D_{max} <= 600 cGy	50

Appendix B

Table VI: Targets for regimen 1 (R_x init=2340 cGy, R_x bst = 3060).

Target Id	**Total R_x (cGy)**	**Plan Id**
PTV_CSI	2340	CSI-Init
PTV_Boost	5400	CSI-bst

Table VII: Tuning structures to be generated for regimen 1 (R_x init=2340 cGy, R_x bst = 3060).

TS Structure Id
BrainStem_PRV
OpticChiasm_PRV
Cochleas_PRV
OpticNrvs_PRV
TS_Eyes
TS_Lenses
TS_ArmsAvoid

Table VIII: Crop and contour overlap with targets for structures regimen 1 (R_x init=2340 cGy, R_x bst = 3060).

OAR Structure Id
BrainStem
OpticChiasm
Cochleas
OpticNrvs

Table IX: Default Rings for regimen 1 (R_x init=2340 cGy, R_x bst = 3060).

Target Id	**Margin from target (cm)**	**Ring thickness**	**Dose level (cGy)**
PTV_CSI	1.5	2.0	1170
PTV_Boost	1.5	2.0	1530

Table X: Planning goals for regimen 1 (R_x init=2340 cGy, R_x bst = 3060).

Structure	**Dosimetric parameter**	**Limit**
PTV_Boost	V95% >=	100%
	D_{max} <=	110%
PTV_CSI	V2340cGy >=	95%
	D_{max} <=	2437 cGy
BrainStem	D_{max} <=	104%
OpticChiasm	D_{max} <=	100%
SpinalCord	D_{max} <=	104%
OpticNrvs	D_{max} <=	100%
Cochleas	D_{max} <=	102%
	D_{mean} <=	3700 cGy
Parotids	D_{mean} <=	1500 cGy
Pituitary	D_{max} <=	110%
Eyes	D_{max} <=	4500 cGy
	D_{mean} <=	3600 cGy
Lenses	D_{max} <=	3600 cGy
Kidneys	D_{mean} <=	1000 cGy
Ovaries	D_{mean} <=	300 cGy
	D_{max} <=	500 cGy
OralCavity	D_{mean} <=	1200 cGy
Thyroid	D_{mean} <=	2000 cGy
Lungs	D_{mean} <=	1000 cGy
Heart	D_{mean} <=	900 cGy
Esophagus	D_{mean} <=	3000 cGy
Glnd_submands	D_{mean} <=	1300 cGy
Larynx	D_{mean} <=	2500 cGy
TS_ArmsAvoid	D_{max} <=	8.3%

Table XI: Optimization constraints for regimen 1 (R_x init=2340 cGy, R_x bst = 3060) initial plan.

Structure	**Optimization constraint**	**Priority**
PTV_CSI	V100% >= 2340 cGy	100
	D_{max} <= 2373 cGy	100
	D98% <= 2353 cGy	100
BrainStem	D_{max} <= 2373 cGy	80
BrainStem_PRV	D_{max} <= 2405 cGy	60
OpticChiasm	D_{max} <= 2223 cGy	80
OpticChiasm_PRV	D_{max} <= 2300 cGy	60
SpinalCord	D_{max} <= 2535 cGy	80
OpticNrvs	D_{max} <= 2223 cGy	80
OpticNrvs_PRV	D_{max} <= 2300 cGy	60
Cochleas	D_{max} <= 2347 cGy	70
	D_{mean} <= 2340 cGy	70
Parotids	D_{mean} <= 780 cGy	60
Pituitary	D_{max} <= 2438 cGy	60
Eyes	D_{max} <= 2373 cGy	60
	D_{mean} <= 2340 cGy	60
Lenses	D_{max} <= 2145 cGy	60
Kidneys	D_{mean} <= 520 cGy	80
Ovaries	D_{mean} <= 200 cGy	60
	D_{max} <= 325 cGy	60
OralCavity	D_{mean} <= 780 cGy	60
Thyroid	D_{mean} <= 1300 cGy	60
Lungs	D_{mean} <= 650 cGy	60
Heart	D_{mean} <= 585 cGy	50
Esophagus	D_{mean} <= 1950 cGy	50
Glnd_submands	D_{mean} <= 845 cGy	50
Larynx	D_{mean} <= 1625 cGy	50
TS_ring1170	D_{max} <= 1170 cGy	80
TS_ArmsAvoid	D_{max} <= 200 cGy	100
TS_Eyes	D_{max} <= 1200 cGy	70
TS_Lenses	D_{max} <= 1000 cGy	70

Table XII: Optimization constraints for regimen 1 (R_x init=2340 cGy, R_x bst = 3060) boost plan.

Structure	**Optimization constraint**	**Priority**
PTV_Boost	V100% >= 3060 cGy	100
	D_{max} <= 3145 cGy	100
	D98% <= 3094 cGy	100
BrainStem	D_{max} <= 2992 cGy	80
BrainStem_PRV	D_{max} <= 2992 cGy	60
OpticChiasm	D_{max} <= 2805 cGy	80
OpticChiasm_PRV	D_{max} <= 2805 cGy	60
SpinalCord	D_{max} <= 2992 cGy	80
OpticNrvs	D_{max} <= 2805 cGy	80
OpticNrvs_PRV	D_{max} <= 2900 cGy	60
Cochleas	D_{max} <= 680 cGy	70
	D_{mean} <= 595 cGy	70
Parotids	D_{mean} <= 510 cGy	50
Pituitary	D_{max} <= 2992 cGy	50
Eyes	D_{max} <= 2992 cGy	50
	D_{mean} <= 1700 cGy	50
Lenses	D_{max} <= 510 cGy	70
TS_ring1530	D_{max} <= 1530 cGy	80
TS_Eyes	D_{max} <= 510 cGy	50
TS_Eyes	D_{mean} <= 425 cGy	50
TS_Lenses	D_{max} <= 170 cGy	70

Appendix C

Table XIII: Targets for regimen 2 (R_x init=3600 cGy, R_x bst = 1800).

Target Id	**Total R_x (cGy)**	**Plan Id**
PTV_CSI	3600	CSI-Init
PTV_Boost	5400	CSI-bst

Table XIV: Tuning structures to be generated for regimen 2 (R_x init=3600 cGy, R_x bst = 1800).

TS Structure Id
BrainStem_PRV
OpticChiasm_PRV
Cochleas_PRV
OpticNrvs_PRV
TS_Eyes
TS_Lenses
TS_ArmsAvoid

Table XV: Crop and contour overlap with targets for structures regimen 2 (R_x init=3600 cGy, R_x bst = 1800).

OAR Structure Id
BrainStem
OpticChiasm
Cochleas
OpticNrvs

Table XVI: Default Rings for regimen 2 (R_x init=3600 cGy, R_x bst = 1800).

Target Id	**Margin from target (cm)**	**Ring thickness**	**Dose level (cGy)**
PTV_CSI	1.5	2.0	1800
PTV_Boost	1.5	2.0	900

Table XVII: Planning goals for regimen 2 (R_x init=3600 cGy, R_x bst = 1800).

Structure	**Dosimetric parameter**	**Limit**
PTV_Boost	V95% >=	100%
	D_{max} <=	110%
PTV_CSI	V3600cGy >=	95%
	D_{max} <=	3750 cGy
BrainStem	D_{max} <=	104%
OpticChiasm	D_{max} <=	100%
SpinalCord	D_{max} <=	104%
OpticNrvs	D_{max} <=	100%
Cochleas	D_{max} <=	102%
	D_{mean} <=	3700 cGy
Parotids	D_{mean} <=	1500 cGy
Pituitary	D_{max} <=	110%
Eyes	D_{max} <=	4500 cGy
	D_{mean} <=	3600 cGy
Lenses	D_{max} <=	3600 cGy
Kidneys	D_{mean} <=	1000 cGy
Ovaries	D_{mean} <=	300 cGy
	D_{max} <=	500 cGy
OralCavity	D_{mean} <=	1200 cGy
Thyroid	D_{mean} <=	2000 cGy
Lungs	D_{mean} <=	1000 cGy
Heart	D_{mean} <=	900 cGy
Esophagus	D_{mean} <=	3000 cGy
Glnd_submands	D_{mean} <=	1300 cGy
Larynx	D_{mean} <=	2500 cGy
TS_ArmsAvoid	D_{max} <=	8.3%

Table XVIII: Optimization constraints for regimen 2 (R_x init=3600 cGy, R_x bst = 1800) initial plan.

Structure	**Optimization constraint**	**Priority**
PTV_CSI	V100% >= 3600 cGy	100
	D_{max} <= 3650 cGy	100
	D98% <= 3620 cGy	100
BrainStem	D_{max} <= 3650 cGy	80
BrainStem_PRV	D_{max} <= 3700 cGy	60
OpticChiasm	D_{max} <= 3420 cGy	80
OpticChiasm_PRV	D_{max} <= 3420 cGy	60
SpinalCord	D_{max} <= 3900 cGy	80
OpticNrvs	D_{max} <= 3420 cGy	80
OpticNrvs_PRV	D_{max} <= 3420 cGy	60
Cochleas	D_{max} <= 3610 cGy	70
	D_{mean} <= 3600 cGy	70
Parotids	D_{mean} <= 1200 cGy	60
Pituitary	D_{max} <= 3750 cGy	60
Eyes	D_{max} <= 3650 cGy	60
	D_{mean} <= 3600 cGy	60
Lenses	D_{max} <= 3300 cGy	60
Kidneys	D_{mean} <= 800 cGy	60
Ovaries	D_{mean} <= 300 cGy	60
	D_{max} <= 500 cGy	60
OralCavity	D_{mean} <= 1200 cGy	60
Thyroid	D_{mean} <= 3000 cGy	60
Lungs	D_{mean} <= 1000 cGy	60
Heart	D_{mean} <= 900 cGy	60
Esophagus	D_{mean} <= 3000 cGy	50
Glnd_submands	D_{mean} <= 1300 cGy	50
Larynx	D_{mean} <= 2500 cGy	50
TS_ring1800	D_{max} <= 1800 cGy	80
TS_ArmsAvoid	D_{max} <= 200 cGy	100
TS_Eyes	D_{max} <= 1200 cGy	70
TS_Lenses	D_{max} <= 1070 cGy	70

Table XIX: Optimization constraints for regimen 2 (R_x init=3600 cGy, R_x bst = 1800) boost plan.

Structure	**Optimization constraint**	**Priority**
PTV_Boost	V100% >= 1800 cGy	100
	D_{max} <= 1850 cGy	100
	D98% <= 1820 cGy	100
BrainStem	D_{max} <= 1760 cGy	80
BrainStem_PRV	D_{max} <= 1760 cGy	60
OpticChiasm	D_{max} <= 1650 cGy	80
OpticChiasm_PRV	D_{max} <= 1650 cGy	60
SpinalCord	D_{max} <= 1760 cGy	80
OpticNrvs	D_{max} <= 1650 cGy	80
OpticNrvs_PRV	D_{max} <= 1650 cGy	60
Cochleas	D_{max} <= 400 cGy	70
	D_{mean} <= 350 cGy	70
Parotids	D_{mean} <= 300 cGy	50
Pituitary	D_{max} <= 1760 cGy	50
Eyes	D_{max} <= 1760 cGy	50
	D_{mean} <= 1000 cGy	50
Lenses	D_{max} <= 300 cGy	70
TS_ring900	D_{max} <= 900 cGy	80
TS_Eyes	D_{max} <= 300 cGy	50
TS_Eyes	D_{mean} <= 250 cGy	50
TS_Lenses	D_{max} <= 100 cGy	70