THE 27th HO CHI MINH CITY ANNUAL CONFERENCE ON CANCER PREVENTION AND CONTROL

5th- 6th, December 2024

Ho Chi Minh, Viet Nam

CAOS: Software for Determining Isocenter Coordinates and Optimizing Collimator Angles in RapidArc Radiosurgery Planning on Eclipse 13.6

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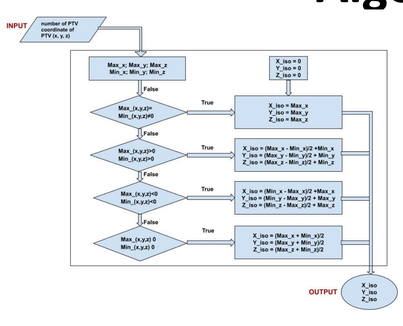
Purpose

This study developed and then evaluated the efficacy and accuracy of the Collimator Angle Optimization Software (CAOS) integrated with the Eclipse 13.6 platform for planning stereotactic radiosurgery (SRS) using RapidArc on the TrueBeam STx system.

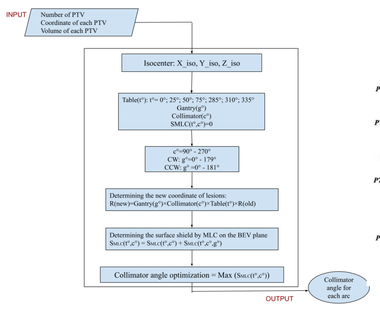
The goal is to optimize isocenter coordinates and collimator angles to improve dose distribution and minimize exposure to normal brain tissue.

Materials and Methods

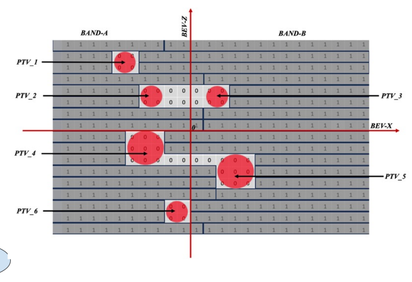
Algorithm Principles



Isocenter Coordinate Determination Algorithm for Radiosurgery Treatment Planning



Collimator Optimization Algorithm for Radiosurgery Treatment Planning



The lesions projected and MLC on the BEV surface xOz

Stereotactic Radiosurgery Plans

CT Simulation
The study involved 25 cases: 10 with two lesions, 10 with three lesions, and 5 with four lesions, all planned with a prescription dose of 18 Gy in 1 fraction

Planning
This plan includes eight arcs, each corresponding to a different couch angle, with an energy of 6 MV FFF and a high dose rate of 1400 MU/min for all plans
Ring_Inner (Shell extends from all lesions with the thickness of 2 mm)
Ring_Middle (Shell extends from all lesions plus 2 mm with the thickness of 3 mm)
Ring_Outer (Shell extends from all lesions plus 5 mm with the thickness of 45 mm)

Plan with Collimator angle from CAOS	Plan with Collimator angle from Eclipse 13.6

Indicators for Planning Evaluation

	RTOG	Paddick 2000
CI	$CI_{RTOG} = \frac{V_{100}}{V_{PTV}}$	$CI_{Paddick} = \frac{{V_{PTV100}}^2}{V_{PTV} \times V_{100}} = \frac{V_{PTV100}}{V_{PTV}} \, x \, \frac{V_{PTV100}}{V_{100}}$
HI	RTOG [3]	Wu Qiuwen [5]
	$HI_{RTOG} = \frac{D_{max}}{D_P}$	$HI_{Wu} = \frac{D_5 - D_{95}}{D_P}$
GI	Paddick 2006 [6]	Wagner 2003 [7]
	$GI_{Paddick} = \frac{V_{PTV50}}{V_{PTV}}$	$GI = 100 - 100x((R_{Eff,\,50\%Rx} - R_{Eff,\,Rx}) - 0.3cm)$

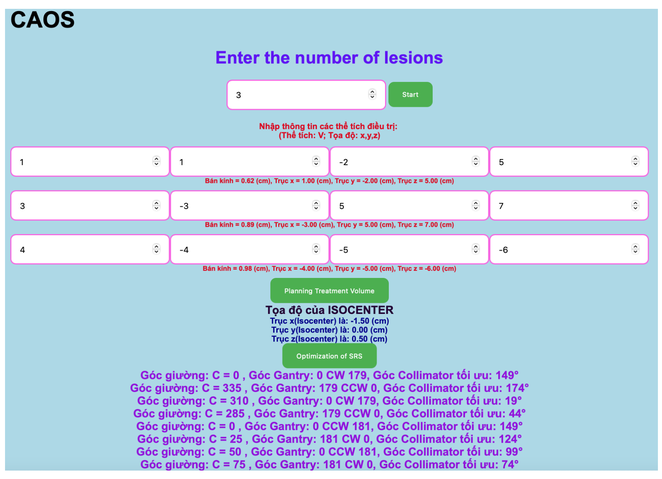
V12 (the healthy brain volume received 12 Gy): When assessing treatment plans, this indicator was expected to be as small as possible

Indicators	Pass	Acceptable
CI_{RTOG}	$1.0 \le CI \le 2.0$	$0.9 \le CI \le 1.0$ $2.0 \le CI \le 3.5$
HI_{RTOG}	$1 < HI \le 2.0$	$2.0 < HI \le 2.5$
$GI_{Paddick}$	$3.0 \le GI \le 5.0$	$1.0 < GI < 3.0$
V12	V12 ≤ 10 cc (Single fraction)	

Results

Function, accuracy and efficient of software

- The CAOS software processed and provided the isocenter coordinates and collimator angles for each case.
- The software does not limit the number of lesions in a treatment plan.
- However, if the number of treatment volumes is high, the processing time to calculate the optimal collimator angles will be longer.
- The software has a user-friendly interface.
- *https://drqtpham.github.io/caosv1/*



The Healthy Brain Volume received 12 Gy

Number of lesion	Plan with Collimator angle from CAOS	Plan with Collimator angle from Eclipse 13.6	P-value
2 PTV	2.44 ± 0.22	2.79 ± 0.29	$\mathbf{p < 0.05}$
3 PTV	3.89 ± 0.18	4.06 ± 0.17	$\mathbf{p < 0.05}$
4 PTV	5.54 ± 0.16	5.71 ± 0.19	$\mathbf{p < 0.05}$

Comparison of CI, GI and GM

A. Two lesions

	Plan with Collimator angle from CAOS	Plan with Collimator angle from Eclipse 13.6	P-value
CI_{RTOG}	1.11 ± 0.01	1.11 ± 0.01	> 0.14
$CI_{Paddick}$	0.60 ± 0.01	0.60 ± 0.01	> 0.33
$GI_{Paddick}$	5.83 ± 0.33	6.59 ± 0.57	$\mathbf{p < 0.05}$
GM	0.52 ± 0.02	0.56 ± 0.03	$\mathbf{p < 0.05}$

B. Thee lesions

	Plan with Collimator angle from CAOS	Plan with Collimator angle from Eclipse 13.6	P-value
CI_{RTOG}	1.091 ± 0.003	1.091 ± 0.005	> 0.47
$CI_{Paddick}$	0.601 ± 0.004	0.599 ± 0.004	> 0.14
$GI_{Paddick}$	6.212 ± 0.202	6.431 ± 0.179	$\mathbf{p \ll 0.05}$
GM	0.628 ± 0.014	0.641 ± 0.013	$\mathbf{p < 0.05}$

B. Four lesions

	Plan with Collimator angle from CAOS	Plan with Collimator angle from Eclipse 13.6	P-value
CI_{RTOG}	1.095 ± 0.003	1.093 ± 0.004	> 0.47
$CI_{Paddick}$	0.602 ± 0.075	0.602 ± 0.005	> 0.14
$GI_{Paddick}$	6.610 ± 0.087	6.781 ± 0.098	$\mathbf{p < 0.05}$
GM	0.728 ± 0.009	0.734 ± 0.009	> 0.26

Conclusions

- ❑ **The CAOS software has demonstrated significant improvements in determining the isocenter coordinates and the optimization of collimator angles for SRS planning using RapidArc.**
- ❑ **The enhanced dose distribution and reduced normal brain dose achieved with CAOS optimization have important clinical implications for improving patient outcomes and minimizing treatment-related side effects.**
- ❑ **These findings support the integration of CAOS into routine clinical practice as a valuable tool for advanced radiosurgery planning.**